S190 Introduction to Wildland Fire Behavior

Evaluation

- There are knowledge checks embedded within the S190 course in the form of exercises and questions. These are not graded but designed to encourage engagement and test yourselves on the material you have learned.

- **Student Task Sheet**:

Print and complete throughout the course and turn into your assigned supervisor.
https://www.nwcg.gov/sites/default/files/training/docs/s-190-student-evaluation-task-sheet.pdf
The task sheet is more of a formal method to demonstrate your understanding of the content. It is very similar to what we call a position task book which is a method of evaluating performance for different positions. Many fire related positions have a position task book that is required before someone can be fully qualified.

Reference Materials

- Incident Response Pocket Guide (2018)
  https://www.nwcg.gov/sites/default/files/publications/pms461.pdf
- NWCG Fire Environment Poster – Factors That Influence Fire Behavior
  An excellent fire behavior reference poster with pictures and descriptions.
  https://www.nwcg.gov/sites/default/files/publications/pms439.pdf
- Fire Weather Cloud Chart PMS 438
  https://www.nwcg.gov/publications/438
- Psychrometric Table
  https://www.nwcg.gov/publications/pms437/weather/temp-rh-dp-tables#TOCElevation-6101-8500ft
- NWCG Glossary of Wildland Fire PMS 205
  Students are encouraged to access it via smart device during the course
  https://www.nwcg.gov/glossary/a-z
- Notebook

Objectives

- Describe the basic terminology used in wildland fire
- Identify and discuss the fire triangle
- Identify & discuss key characteristics - primary wildland fire environment - fuels, weather, & topography
- Identify critical fire weather factors that, combined with receptive fuels, may result in extreme fire behavior
- Recognize how alignment of fuels, weather, & topography can increase the potential for extreme fire behavior

Course Overview

- UNIT 1 Basic Concept of Wildland Fire
- UNIT 2 Fuels
- UNIT 3 Temperature and Moisture Relationships
- UNIT 4 Topography
- UNIT 5 Atmospheric Stability, Winds & Clouds
- UNIT 6 Critical Fire Weather
- UNIT 7 Alignment

UNIT 1 Basic Concept of Wildland Fire

Objectives

- Describe basic terminology used in wildland fire
- Describe the elements of the fire triangle
- Describe the methods of heat transfer

Students are encouraged to access it via smart device during this unit
NWCG Glossary of Wildland Fire PMS 205 https://www.nwcg.gov/glossary/a-z

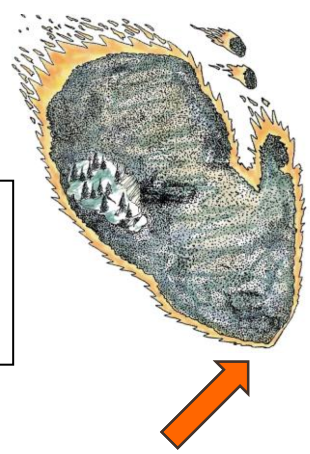
WATCH VIDEO: Basic Fire Terminology Summary (02:20)
This is representative of a ground resource communicating with an air resource who is able to provide a bird's eye view of the situation. In this scenario, firefighters have arrived on scene of a new fire. They are gathering and communicating their situational awareness of the current fire behavior.

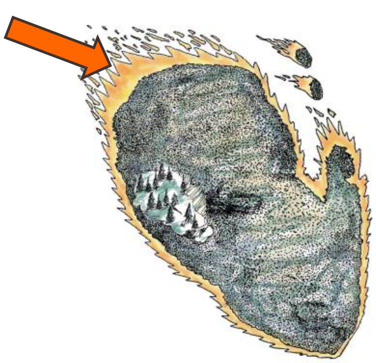
ACTION During the video: Write down as many basic fire terms as possible AND then after the video reference them in the NWCG Glossary of Wildland Fire

TERMINOLOGY - PARTS OF A FIRE

FIRE PERIMETER
The entire outer edge or boundary of a fire

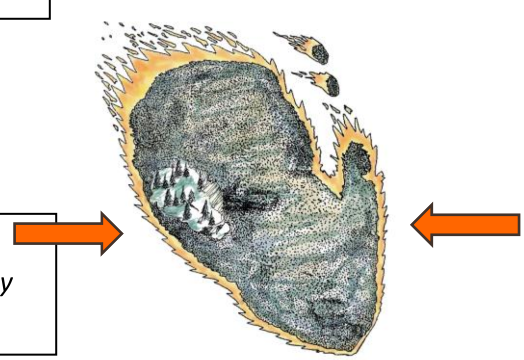
POINT OF ORIGIN
The location where a competent ignition source came into contact with the material first ignited and sustained combustion occurred.

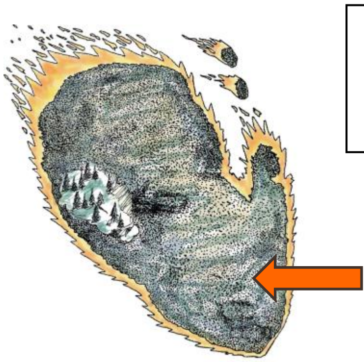




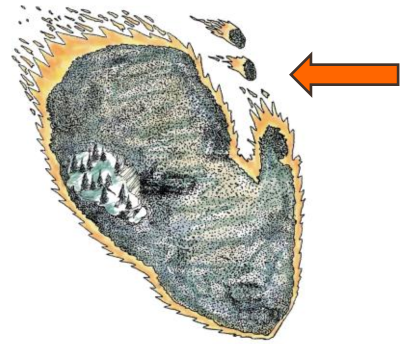
HEAD
The most rapidly spreading portion of a fire's perimeter, usually to the leeward or up slope.

FLANKS
The parts of a fire's perimeter that are roughly parallel to the main direction of spread.

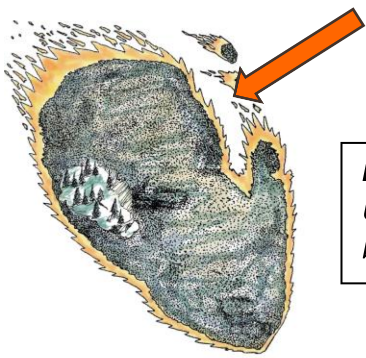




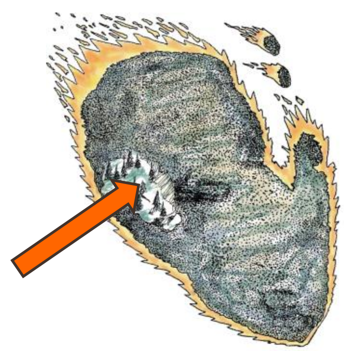
REAR OR HEEL
That portion of a fire edge opposite the head. Slowest spreading portion of a fire edge.



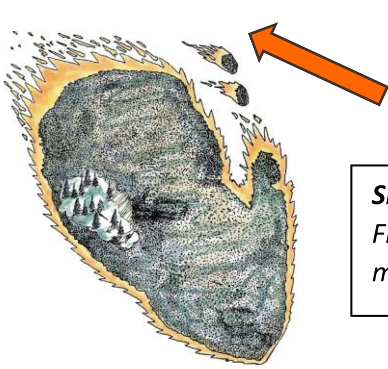
FINGER
The long narrow extensions of a fire projecting from the main body.



POCKET
Unburned indentations in the fire edge formed by fingers or slow burning areas.



ISLAND
An unburned area within a fire perimeter.



SPOT
Fire ignited outside the perimeter of the main fire by a firebrand.

EXERCISE - TERMINOLOGY - SUPPRESSION

For the following terms write down a simple description and where or how the term applies to the fire image.

ANCHOR POINT

CONTROL LINE

FIRELINE

MOPUP

CONTAINED

CONTROLLED

CHAIN

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ANSWERS - EXERCISE - TERMINOLOGY - SUPPRESSION

ANCHOR POINT

An advantageous location, usually a barrier to fire spread, from which to start constructing a fireline. The anchor point is used to minimize the chance of being flanked by the fire while the line is being constructed.

CONTROL LINE

An inclusive term for all constructed or natural barriers and treated fire edges used to contain a fire.

FIRELINE

The part of a containment or control line that is scraped or dug to mineral soil.

MOOPUP

Extinguishing or removing burning material near control lines, felling snags, and trenching logs to prevent rolling after an area has burned, to make a fire safe, or to reduce residual smoke.

CONTAINED

The status of a wildfire suppression action signifying that a control line has been completed around the fire, and any associated spot fires, which can reasonably be expected to stop the fire’s spread.

CONTROLLED

The completion of control line around a fire, any spot fires, and any interior islands to be saved. Burn out any unburned area adjacent to the fire side of the control lines.   Cool down all hotspots that are immediate threats to the control line, until the lines can reasonably be expected to hold under the foreseeable conditions.

CHAIN

Unit of measure in land survey, equal to 66 feet (20 M) (80 chains equal 1 mile). Commonly used to report fire perimeters and other fireline distances. Popular in fire management because of its convenience in calculating acreage (example: 10 square chains equal one acre).

TERMINOLOGY – BASIC FIRE BEHAVIOR

When looking at each picture, it is important to recognize and be able to describe the character of the fire behavior.

Reference Fire Behavior Hauling Chart in the *Incident Response Pocket Guide (IRPG)*
https://www.nwcg.gov/publications/461

SMOLDERING
Fire burning without presence of flame or direct flame and barely spreading.

CREEPING
Fire burning with a low flame and slowly spreading.

RUNNING
Behavior of a fire spreading rapidly with a well-defined head.

SPOTTING
Behavior of a fire producing sparks or embers that are carried by the wind and which start new fires beyond the zone of direct ignition by the main fire.

TORCHING
The burning of the foliage of a single tree or a small group of trees, from the bottom up.

FLARE-UP
Any sudden acceleration in the rate of spread or intensification of the fire. A flare-up is of relativity short duration and does not change existing control plans.

FIRE WHIRL
Spinning vortex column of ascending hot air and gases rising from a fire and carrying aloft smoke, debris, and flame.

BACKING
That portion of the fire with slower rates of fire spread and lower intensity, normally moving into the wind and/or down slope.

FLAMING FRONT
That zone of a moving fire where the combustion is primarily flaming.

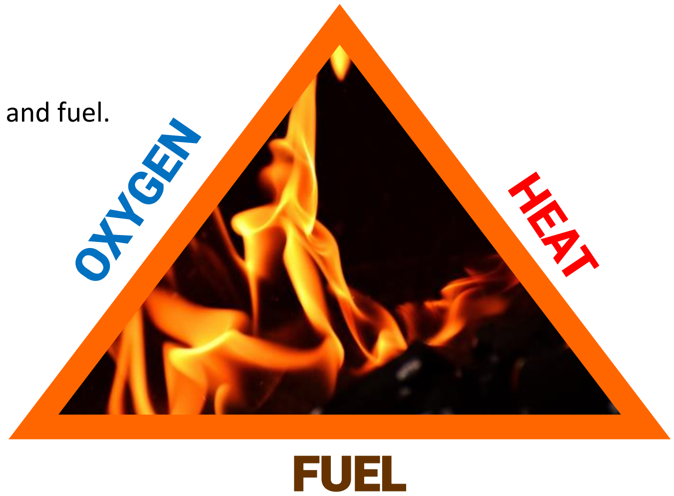
CROWNING
A fire that advances from top to top of trees or shrubs more or less independent of a surface fire.

- **WATCH VIDEO:** [Cascade Crown Fire Run](#) (00:34)

- **WATCH VIDEO:** [Torching Tree](#) (00:31)

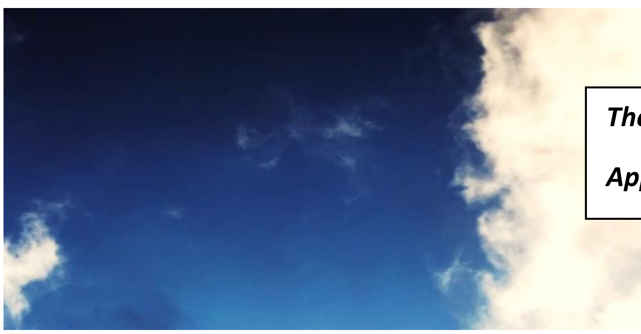
THE FIRE TRIANGLE

- Three elements comprise the fire triangle: oxygen, heat, and fuel.
- These three elements must be present and combined before combustion can occur and continue.



OXYGEN

- The most abundant chemical element on earth is oxygen.
- Oxygen supports the chemical processes that occur during a wildfire.
- When fuel burns, it reacts with oxygen from the surrounding air, releasing heat, and generating combustion products such as gases, smoke, and embers. This process is known as oxidation.



The air we breathe contains 21% OXYGEN

Approximately 16% is required for combustion

HEAT

- A heat source is responsible for initial ignition of a wildfire and is also needed to maintain
- the fire and enable it to spread.
- Lightning is the most common natural source of heat.
- Humans can cause heat leading to wildland fires.

Question: Where does human-caused heat come from?
Abandoned campfires, arson, matches, dragging chains, burning trash, etc.

Natural -OR- Human Caused

FUEL

- Fuel is the material that is burning.
- Fuel can be any kind of combustible material, especially petroleum-based products, and wildland fuels.

Fuel types will be discussed in Unit 2

- ***Grass***
- ***Shrub***
- ***Timber***
- ***Slash***
- ***Artificial materials***

BREAKING THE FIRE TRIANGLE: ***Removal of one or more elements of the triangle***

WATCH VIDEO: WFSTAR The Fire Triangle (7:26)

HEAT OXYGEN FUEL

Question: How might you break the fire triangle from the fuel element?

Answer: Removal of fuel by clearing space.

Question: How might you break the fire triangle from the oxygen element?

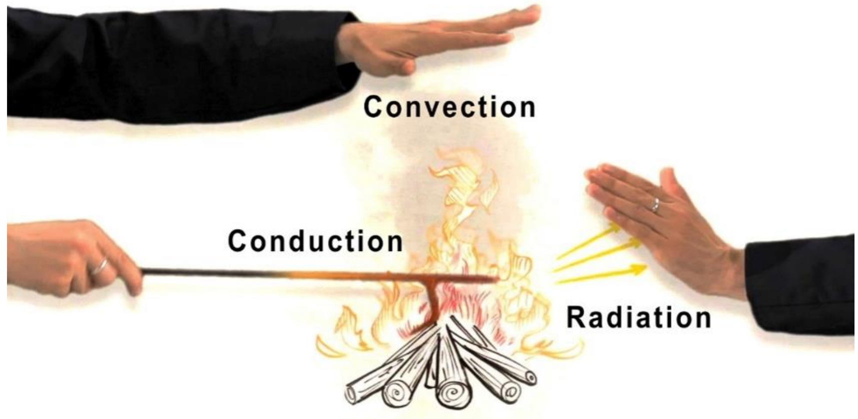
Answer: Removal of oxygen by restricting the oxygen supply.

Question: How might you break the fire triangle from the heat element?

Answer: Removal of heat by applying water, dirt, or other methods.

- **METHODS OF HEAT TRANSFER:**
The process by which heat is imparted from one body to another, through conduction, convection, and radiation.

- **WATCH VIDEO:**
[Different Modes of Heat Transfer](#) (2:33)



CONDUCTION: ***The transfer of heat through direct contact.***

- Think of conduction as a spoon in a hot drink. Heat is conducted from one fuel particle to another in the same way, through direct contact.
- Since wood is a poor conductor (meaning heat will not travel through it easily), this process is less of a factor to fire behavior.

CONVECTION: ***The transfer of heat by the movement of a gas or liquid.***

- Convection occurs when lighter warm air moves upward.
- Think of convection as a smoke column above the fire. The hot gases and embers which compose the smoke column move and can dry and ignite other fuels.

RADITION: ***Transfer of heat in a straight line through a gas or vacuum other than by heating of the intervening space.***

- Radiant heat warms you as you stand close to a campfire or stand in the sunlight.
- Radiant heat can dry surrounding fuels and sometimes ignite them.

END OF UNIT 1

Please review the objectives below and answer the questions on your Task Sheet that relate to Unit1.

Objectives

- Describe the basic terminology used in wildland fire
- Identify and discuss the fire triangle
- Identify & discuss key characteristics - primary wildland fire environment - fuels, weather, & topography
- Identify critical fire weather factors that, combined with receptive fuels, may result in extreme fire behavior
- Recognize how alignment of fuels, weather, & topography can increase the potential for extreme fire behavior

UNIT 2 Fuels

Objectives

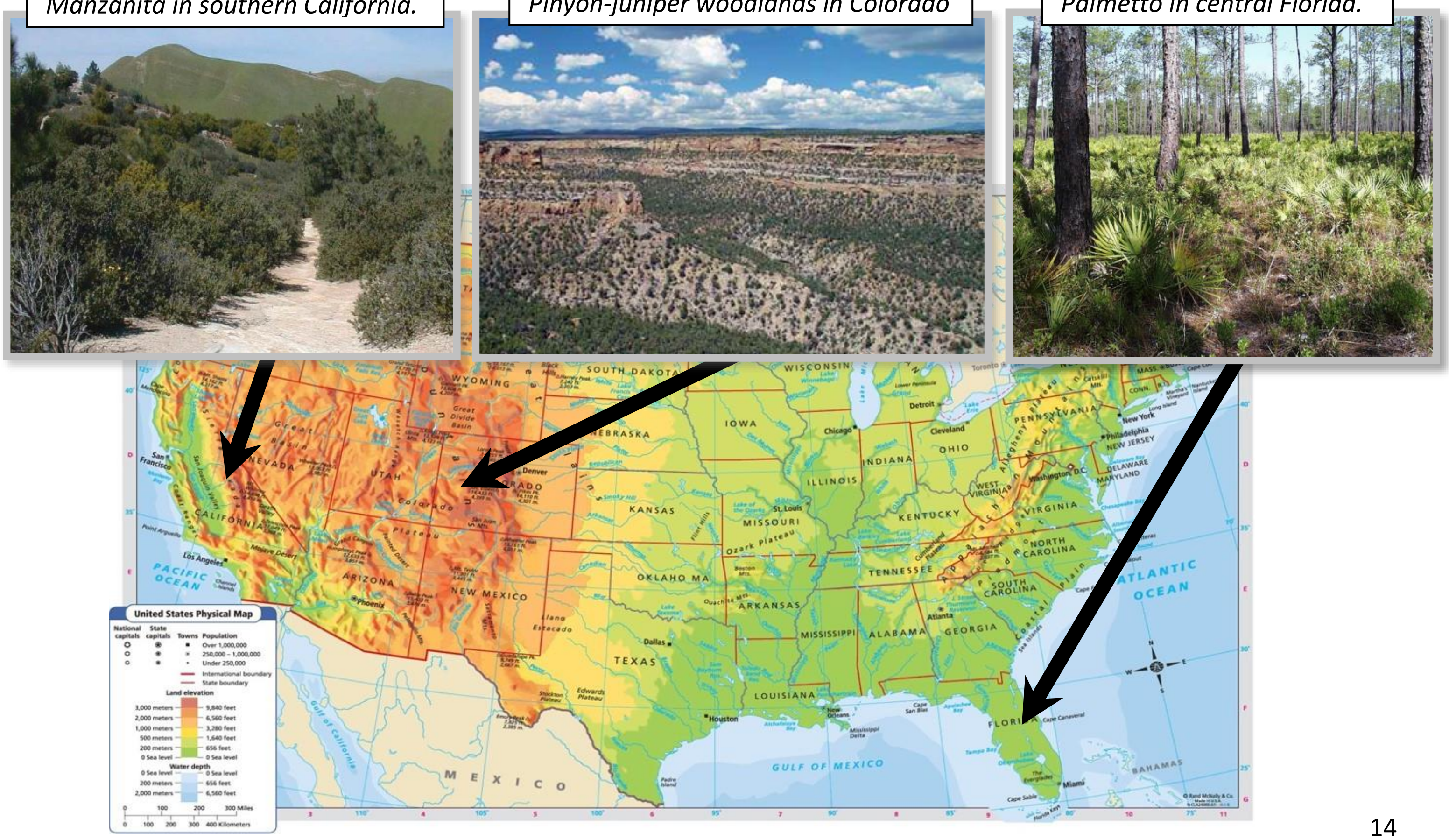
- Describe the term fuels
- Describe how fuel type and fuel characteristics affect fire behavior

What is fuel?

- Fuel is the material that is burning. It can be any kind of combustible material, especially petroleum-based products, and wildland fuels.
- For wildland fire, it is usually live, or dead plant material, but can also include artificial materials.
- Artificial materials are items such as houses, sheds, fences, pipelines, and trash piles.

FUEL DISTRIBUTION

- Firefighters can be called to respond to incidents in different parts of the country, climate zones, and fuel types.
- There are geographic and regional distinctions across the country in regards to the predominate fuel types in the area.
- The amount of water in the soil and elevation change are some of the reasons behind different fuel types.



Manzanita in southern California.

Pinyon-juniper woodlands in Colorado

Palmetto in central Florida.

FUEL TYPE

Fuel Type: An identifiable association of fuel elements of distinctive species, form, size, arrangement, or other characteristics that will cause a predictable rate of spread or resistance to control under specified weather conditions.
Man-made fuels are referred to as artificial fuels in the wildland fire context.
Reference Common Denominators of Fire Behavior on Tragedy Fires in the *Incident Response Pocket Guide* (IRPG)

Wildland fuels are grouped into six fuel types, based on the primary fuel that carries the fire.

1. **Grass**
2. **Shrub**
3. **Grass-Shrub**
4. **Timber Litter**
5. **Timber-Understory**
6. **Slash-Blowdown**

GRASS

- Located in all regions of the country, grass is the predominant fuel found in desert and range regions.
- Responds quickly to wind and changes in relative humidity, and burns the fastest of the fuel types. It is common to hear the term wind-driven when referring to grass fires, due to the impact wind can have on this fuel.
- Fire can spread very quickly, but can also burn out very quickly, leaving areas safe to move through just seconds after the flaming front passes.
- Potential to become the prevalent fuel in an area after a fire has occurred. For example, after a fire in timber, grass will regenerate first, introducing a new predominate fuel to that area.

SHRUB

- Shrubs are found in most regions and include some low-growing trees, such as scrub oaks.
- May burn very actively, or may slow the spread of fire depending on type of shrub and time of year.
- The shrub type is highly influenced by drought conditions.
- When the shrub type is receptive, it has the potential to spread fire quickly.

GRASS-SHRUB

- Commonly found in the plains regions and high deserts, grass-shrub is a mixture of fine grass and shrubs.
- Fire behavior in this type combines the features of the grass fuel type and the shrub fuel type.
- Fires may spread rapidly with wind, but more slowly than a grass fuel type.
- Shrubs add intensity to the fire and may produce spotting, but fires are less intense than in the Shrub type.
- Where it may be safe to move in the grass type immediately after fire passes, it may not be safe in this type because of longer-burning shrubs.

TIMBER LITTER

- Timber litter refers to dead leaves, needles, and twigs on the forest floor.
- Fires generally move more slowly in timber types than in grass or shrubs, but burn for longer, and are harder to control.
- When fires burn through the upper canopy of trees they can move very quickly and with extreme intensity.

TIMBER UNDERSTORY

- Timber-understory refers to a canopy of trees with other plants (such as shrubs and small trees) growing below them.
- Fires in this type combine the features of the timber litter type and the shrub type, moving faster than fires in timber litter, but burning longer than fires in shrubs.
- Fires in this fuel type can move very quickly and with intensity, especially when understory trees/shrubs act as a ladder for fire to climb into the upper canopy.

SLASH-BLOWDOWN

- Slash-blowdown is debris resulting from such natural events as wind, fire, or snow breakage, or human activities such as road construction, logging, pruning, thinning, or brush cutting.
- Fire in this fuel type does not commonly spread quickly. However, due to the sheer amount of fuel that is available, a fire that is established in this fuel type can be very intense and difficult to extinguish.
- Slash typically includes: Logs.Chunks of wood. Bark. Branches. Stumps. Broken understory trees or brush.

ARTIFICIAL

- Although not necessarily considered a fuel type, artificial, or constructed fuels are often present in the wildland environment.
- In many cases, the location of artificial fuels, such as trash piles, or drug production facilities, is unknown until discovered by firefighters.
- Examples of artificial or constructed fuels include: Houses. Vehicles. Tires. Trash. Log decks. Above ground oil and natural gas pipelines.
- Artificial or constructed fuels can present special hazards, such as toxic chemicals, and explosion potential, to wildland firefighters.

AVAILABLE FUEL

The portion of the total fuel that would burn under various environmental conditions.

- Fuels availability for combustion is dependent on its characteristics. However, species of the plant, its age, and the time of year are other important factors.
- For dead fuels, fuel moisture content depends on how much moisture is in the environment and how quickly the fuel absorbs or loses moisture.

FUEL CHARACTERISTICS

- Fuel characteristics influence how fires typically behave.
- The different fuel types can vary in behavior due to their specific characteristics.
- Example: A timber fuel type in the Pacific Northwest region may have different characteristics than the same timber fuel type in the Eastern region.
- Identifying fuel characteristics can give an estimated prediction of fire behavior.

Reference Look Up, Down and Around in the *Incident Response Pocket Guide* [(IRPG)]

FUEL LOADING

CHEMICAL CONTENT

FUEL ARRANGEMENT

MOISTURE CONTENT

SIZE & SHAPE

FUEL LOADING

- The amount of fuel present expressed quantitatively in terms of weight of fuel per unit area. This may be available fuel (consumable fuel) or total fuel and is usually dry weight.
- Dry weight of fuels refers to what the fuels would weigh dry.
- The loading of fuels in any given area does not necessarily mean that fire will burn with great intensity.

Amount of fuel in a given area.
Expressed in tons per acre.
Dry weight of fuel.

CHEMICAL CONTENT

- Chemical content refers to the presence of substances in the fuel such as: Oils. Resins. Wax. Pitch
- Fuels with high amounts of these substances can contribute to rapid rates of spread and high fire intensities.
- Some well known fuels in which these substances exist are:
  - Palmetto in the Southeast.
  - Tamarisk in the Southwest.
  - Many of the chaparral shrubs found in California.

Some fuels can burn at higher intensity because of chemicals in their leaves

FUEL ARRANGEMENT

HORIZONTAL CONTINUITY

- Horizontal, continuous fuels are closely packed and in direct contact with one another.
- Two main categories:
  1. Uniform Fuels.
  2. Patchy Fuels.

Arrangement of fine and course fuels over a certain area horizontally.

UNIFORM FUELS

- Uniform, continuous fuels describe areas containing a network of connected fuels, allowing a continuous path for fire to spread.
- The fuels affect the rate of ignition and spread potential by allowing fire to move steadily from one piece of fuel to the next.

Fuels distributed continuously over an area and in contact with each

PATCHY FUELS

- Refers to areas where the horizontal continuity is disrupted by things like:
    - Rocks.
    - Bare dirt.
    - An intermixing with a fuel type that is much less flammable, such as green grass, or aspen trees.

Fuel distributed unevenly over an area, with definite breaks or barriers

VERTICAL FUEL ARRANGEMNT

- Vertical arrangement of fuels is broken into four categories:

1. Ground fuels
2. Surface fuels
3. Ladder fuels
4. Aerial fuels

Fuels above ground and their vertical continuity, which influences fire

GROUND FUELS

- All combustible materials below the surface litter, including duff, tree, or shrub roots, punky wood, peat, and sawdust, which normally support a glowing combustion without flame.
- Ground fuels do not spread fire quickly, but they can pose problems for containing fires.
- Ground fuels burn below the surface of the ground, out of sight, making it difficult to detect. They can burn for extended periods–weeks, and, in some cases, years.
- Smoldering ground fuels can burn underneath firelines and cause fires to spread out of containment lines.

- Deep duff
- Roots
- Rotten buried logs
- Peat
- Other organic material

SURFACE FUELS

- Fuels lying on or near the surface of the ground, consisting of leaf, and needle litter, dead branch material, downed logs, bark, tree cones, and low stature living plants.
- Includes most of the material we think about as fuel for wildland fires and are the primary carriers of fire once ignition has occurred.
- The primary fuel to remove to break the fire triangle.

- Needles or leaves
- Duff
- Grass
- Small dead wood
- Logs or tree stumps
- Large limbs
- Low shrubs

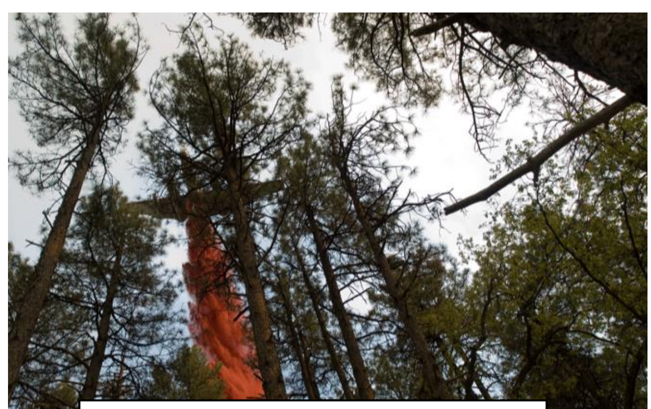
LADDER FUELS

- Fuels that provide vertical continuity between strata, thereby allowing fire to carry from surface fuels into the crowns of trees or shrubs with relative ease. They help initiate and assure the continuation of crowning.
- Ladder fuels allow fires to move from surface fuels, where firefighters are most effective at stopping fires, to burning in aerial fuels where firefighters are not effective at stopping fire.

- Surface fuel
- Small trees or shrubs
- Low branches
- Moss or lichen on tree trunks
- Other moderate height vegetation

AERIAL FUELS

- Standing and supported live and dead combustibles not in direct contact with the ground and consisting mainly of foliage, twigs, branches, stems, cones, bark, and vines.
- Often referred to as canopy or crown fuels.
- Suppression tactics or tools are not very effective at stopping fires burning through aerial fuels (crown fires).
- Fires moving through aerial fuels (crown fires) can be extremely intense and rapid. Embers from crown fires can travel more than a mile ahead of the fire and perpetuate fire growth.



- Upper portion of trees
- Tree branches
- Standing dead trees
- Tall shrubs

MOISTURE CONTENT

Amount of water in a fuel, expressed as a percentage

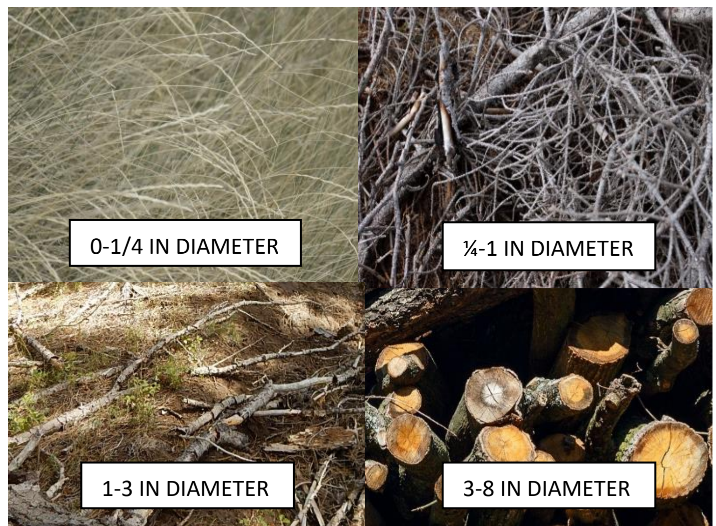
Moisture content is the single most important factor in determining how well a fuel will ignite and burn.

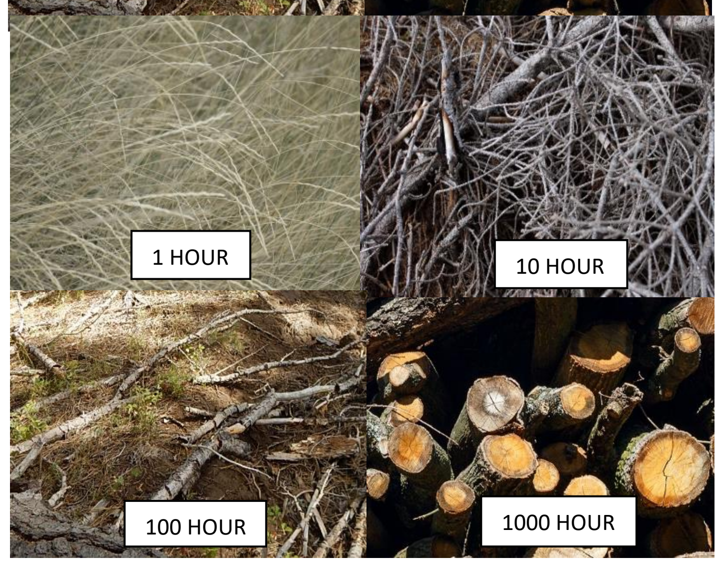
Two categories:

1. ***Live Fuel*** – Living plants, such as trees, grasses, and shrubs. The moisture content in live fuels is controlled by plant species, age of the plant, time of year, and drought conditions.
2. ***Dead Fuel*** – Fuels with no living tissue. The moisture content in dead fuels is controlled by humidity, precipitation, sunlight, wind, and the size, and shape.

- In general, at the height of the growing season, live fuel moistures will be at their highest and will progressively decrease throughout the fire season, whereas dead fuel moistures can fluctuate frequently throughout the fire season based on immediate precipitation, relative humidity, and sunlight.
- Due to variations in characteristics, as well as size, different fuels located in the same area will have varying moisture levels.
- The drier a fuel is, the more likely it is to catch fire and the hotter it will burn.

SIZE AND SHAPE





For dead fuels, the size and shape of a fuel determines how the fuel reacts to its environment and how long it takes to dry out or absorb moisture.

- Size and shape classifications are:
  - 0–1/4” diameter
  - 1/4”–1” diameter
  - 1”–3” diameter
  - 3”–8” diameter
- Fuels within the same size class are assumed to have similar drying and wetting properties, as well as preheating, and ignite at similar rates.
- Smaller fuels dry out and or absorb moisture faster than larger fuels.
- Size and shape classifications correspond to the time it takes a piece of fuel to change its moisture content to match its environment.
- This time period is referred to as timelag, which is the rate at which dead fuel gains or loses moisture.
- Timelag rate classifications are:
- Fuels 0–1/4” in diameter = 1 hour.
- Fuels ¼”–1” in diameter = 10 hours.
- Fuels 1”–3” in diameter = 100 hours.
- Fuels 3”–8” in diameter = 1000 hours.
- Example: Fuels that are 0-1/4” in diameter take one hour to change moisture content from where it started to that of the surrounding environment. Fuels that are 1”–3” will take 100 hours.
- Fuels larger than 8” in diameter are also classified as 1000 hour fuels.

EXERCISE – Answer the following

What is the Fuel Type?

How would you describe the arrangement?

Describe how fire can transition from the ground fuels to the aerial fuels.

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EXERCISE - ANSWER

What is the Fuel Type?

GRASS

How would you describe the arrangement?

CONTINUOUS AND UNIFORM

Describe how fire can transition from the ground fuels to the aerial fuels.

Fire becomes established in the ground fuels, spreads into the surface fuels, transitions into the ladder fuels, and reaches the aerial fuels.

END OF UNIT 2

Please review the objectives below and answer the questions on your Task Sheet that relate to Unit2.

Objectives

- Describe the term fuels.
- Describe how fuel type and fuel characteristics affect fire behavior.

UNIT 3 Temperature and Moisture Relationships

Objectives

- Describe dry bulb temperature, wet bulb temperature, dew point, and relative humidity
- Describe how temperature and relative humidity can influence wildland fire behavior
- Determine relative humidity and dew point by using a Psychometric Table and given inputs

WATCH VIDEO: Introduction to Fire Weather (1:24)
An introduction to fire weather, its causes, impacts, and effects on the fire environment.

WATCH VIDEO: Temperature and Moisture Relationships (00:47)
A brief introduction to the relationship between temperature and moisture in the fire environment.

DRY BULB TEMPERATURE

The temperature of the air measured in the shade, 4 to 8 feet above the ground.

- Dry bulb temperature is the air temperature in our day-to-day lives. When it's 86 °F outside, it refers to the dry bulb temperature.
- Air temperature readings are taken 4 to 8 feet above the ground, either by manual observations, or by automated weather stations.
- Fahrenheit and Celsius are the most common temperature scales used in the world.

WET BULB TEMPERATURE

The lowest temperature to which air can be cooled by evaporating water.

- Evaporation is a cooling process (the opposite of condensation) which results in a decrease in wet bulb temperature.
- Wet bulb temperature is a good indicator of atmospheric moisture but not a direct measurement. For example, little or no drop in wet bulb temperature indicates a moist air mass because little or no evaporation has taken place. On the other hand, a wet bulb decrease of 10° to 15° from the starting point would indicate a much drier air mass.
- It is important not to confuse wet bulb temperature with dew point temperature.

DEW POINT TEMPERATURE

The temperature to which air must be cooled to reach saturation. One of the most reliable methods for measuring atmospheric moisture.
or example, if the dry bulb temperature is 80 °F and the dew point temperature is 50 °F, the dry bulb temperature must decrease by 30 °F (down to 50 °F) for the air to become saturated.

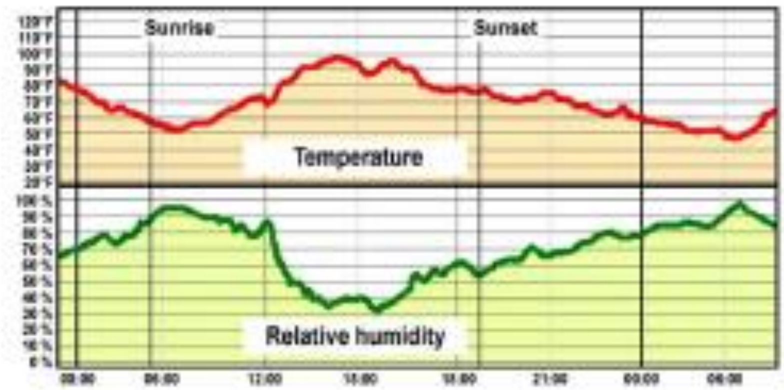
- Dew point temperature is one of the most reliable methods for measuring atmospheric moisture.
- Dew point temperatures may change little from day to day.
- Dew point temperature can be determined with a sling psychrometer with the aid of Psychrometric Tables or Relative Humidity tables in the IRPG.
- A handheld electronic weather meter can also be used for providing dew point temperature. However, the handheld device must meet specifications in the NWCG Standards for Fire Weather Stations, PMS 426-3, https://www.nwcg.gov/publications/426-3.
- Dew point may impact a region with consistent dew point values (more predictable) day to day.

RELATIVE HUMIDITY

The ratio of the amount of moisture in the air to the maximum amount of moisture that air would contain if it were saturated.

- Relative humidity is expressed as a percentage and can range from 1% (very dry) to 100% (very moist).
- Moisture in the air, whether in the form of water vapor, cloud droplets, or precipitation, is the primary weather element that affects fuel moisture content.
- The amount of moisture that fuels can absorb from or release to the air depends largely on relative humidity.
- Light fuels, such as grass, gain and lose moisture quickly with changes in relative humidity. Heavy fuels respond to humidity changes at a slower rate.
- Relative humidity is not a direct measurement of atmospheric moisture but a measure of how much moisture currently exists.

TEMPERATURE AND RELATIVE HUMIDITY



Temperature and relative humidity have an inverse relationship; when one goes up, the other goes down.

- There can be a large fluctuation of temperature and relative humidity based on time and location. However, the majority of large fires occur when air temperature is high and relative humidity is low.
- The graph depicted is an example of a reading from a hygrothermograph, which displays temperature, and relative humidity.
- Maximum temperature for the day typically corresponds to the lowest relative humidity reading for the day (usually occurs mid-afternoon, but dependent on time of year and aspect).
- Minimum temperature for the day typically corresponds to the highest relative humidity reading for the day (usually occurs just after sunrise, but also dependent on time of year and aspect).

TEMPERATURE. RH. FUELS

- Changes in temperature and relative humidity have similar impacts on fuels from one part the country to the next. However, breakpoints for when fuels ignite and burn differ based on climate zone.
- Critical relative humidity values in Florida are typically 30% to 35%, while in the western U.S.; they are typically 15% or lower.

GATHERING TEMPERATURE AND MOISTURE OBSERVATIONS - ***Automated Weather Stations***

- It is very important to routinely monitor temperature and relative humidity trends.
- Fixed and Remote Automated Weather Stations provide hourly observations to a local database via satellite. The observations provide weather data on temperature, humidity, precipitation, wind speed, and solar radiation.
- The observations are monitored by meteorologists and dispatch centers and are used in planned ignitions, wildfires, and on other incidents, and projects to relay current weather information representative of an area of interest.
- Fixed Automated Weather Stations are located in permanent locations throughout the country.
- Remote Automated Weather Station (RAWS or Fire RAWS) are portable units set up in temporary locations to represent a small geographic area, such as a specific fire or incident.

GATHERING TEMPERATURE AND MOISTURE OBSERVATIONS – ***Belt Weather Kit***

- A Belt Weather Kit is a belt-mounted case with pockets fitted for anemometer, compass, sling psychrometer, slide rule, water bottle, pencils, and book of weather report forms.
- Belt Weather Kits are used to take weather observations to provide on-site conditions to the fire weather forecaster or Fire Behavior Analyst (FBAN). Observations include air temperature, wind speed and direction, and relative humidity.
- The Belt Weather Kit is one of the most common methods of obtaining weather observations in the field.
- Use of a Belt Weather Kit is often referred to as slinging or spinning weather, due to the use of the sling psycrometer.

WATCH VIDEO: Belt Weather Kit Tutorial (7:20)
A tutorial of the Belt Weather Kit and how to accurately sling and record weather.

GATHERING TEMPERATURE AND MOISTURE OBSERVATIONS – ***Handheld Fire Weather Meters***

- A handheld fire weather meter is an electronic device that measures temperature, humidity, wind speed, and possibly other atmospheric variables, depending on brand, and model.
- Handheld fire weather meters are used to take weather observations to provide on-site conditions to the fire weather forecaster or Fire Behavior Analyst (FBAN). Observations include air temperature, wind speed and direction, and relative humidity.
- There are several manufacturers of these meters. A handheld weather meter is often referred to as a Kestrel, a common brand name.
- Regardless of make or model, all handheld weather devices must meet the specified NWCG performance standards, as outlined in the NWCG Standards for Fire Weather Stations, PMS 426-3, https://www.nwcg.gov/publications/426-3.

WATCH VIDEO: Digital Weather Meter Tutorial (5:32)
An introduction to the abilities, guidelines, and uses of digital weather meters.

GATHERING TEMPERATURE AND MOISTURE OBSERVATIONS – ***Psychrometric Tables***

Psychrometric tables are used to calculate dew point and relative humidity based on the observations obtained in the field by either a Belt Weather Kit or handheld fire weather meter.

★ Familiarize yourself on how to locate and read the following elements of table:

- o Location of dry bulb temperature.
- o Location of wet bulb temperature.
- o Location of dew point.
- o Location of relative humidity.

The tables are a mandatory component of the Belt Weather Kit. All kits should be inspected prior to use in the field, to ensure the tables are available and intact.

Use the tables for elevation of 6101-8500 ft:
Locate dry bulb temperature of 95 °F
Locate wet bulb temperature or 56 °F
Determine dew point and relative humidity

Belt Weather Kits will be reviewed on the field day exercises.

ANSWER

Dew Point = 22 °F

Relative Humidity = 7%

FACTORS THAT IMPACT TEMPERATURE AND RELATIVE HUMIDITY

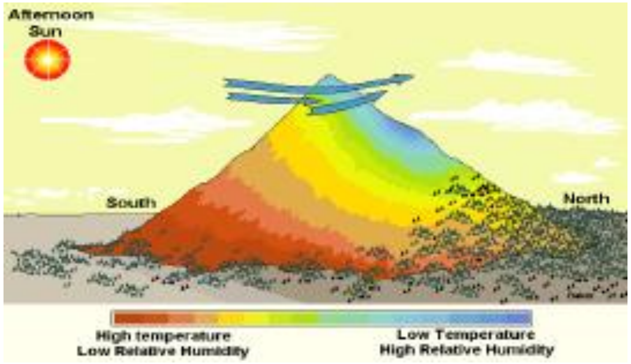
- Elevation
- Topography
- Cloud Cover
- Wind
- Proximity to bodies of water

ELEVATION

Elevation can impact variations in temperature and relative humidity.

- Warmer temperatures and lower RH values are found in the lower elevations (lower valleys and lower foothill regions).
- Cooler temperatures and higher RH values are found in the higher elevations (upper third of slopes and ridgetops).

TOPOGRAPHY



- Topography can influence variations in temperature and relative humidity.
- Aspect is a feature of topography, which determines how much direct sunlight, and solar heating is received.
- South and west-facing slopes receive more incoming solar radiation, especially during the afternoon, and have hotter temperatures, and lower RH values.
- North-facing slopes typically experience less solar radiation and have cooler temperatures and higher RH values.
- Different aspects represent different climate zones in terms of weather, fuel type, fuel moisture, and overall potential fire behavior.
- An understanding of aspect and time of day provides the firefighter knowledge of possible changes in fire behavior.

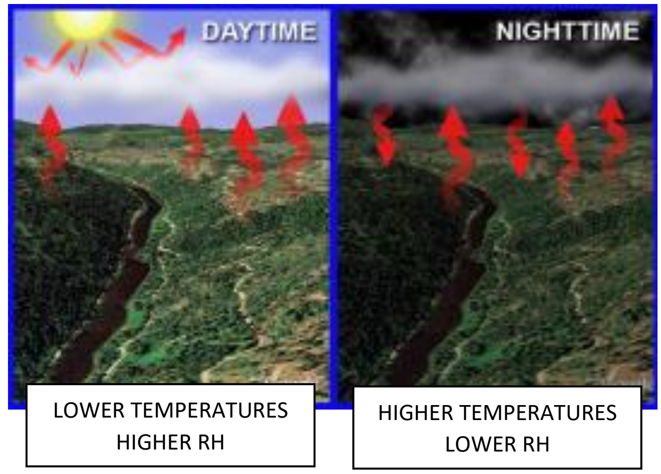
QUESTION: If you are responding to a fire on a south aspect at 1000, what changes in temperature, and RH can you anticipate occurring by 1500?

ANSWER:

The south aspect would have received an increase in solar radiation between 1000 and 1500. Therefore, the temperatures have increased, and the RH has dropped, leading to drier fuels.

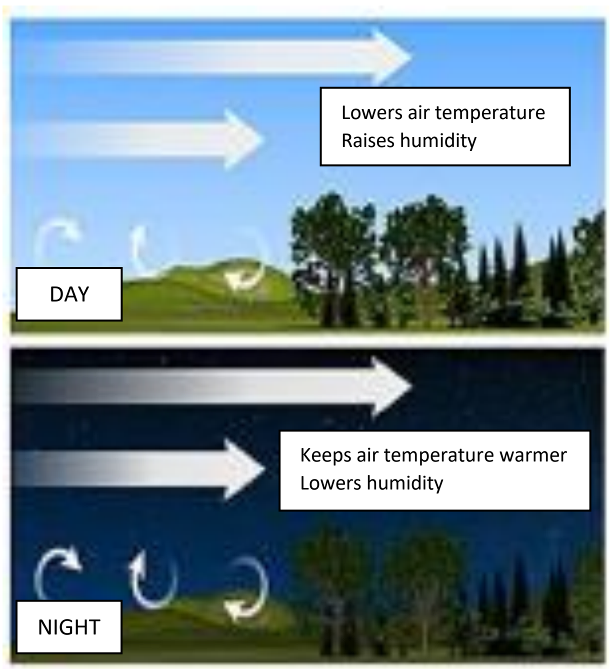
CLOUD COVER

- Cloud cover affects temperature and relative humidity by reflecting incoming sunlight during the day and intercepting outgoing long-wave, terrestrial radiation at night.
- During the day, cloud cover keeps temperatures cooler and RH higher.
- At night-cloud cover keeps temperatures warmer and RH lower (clouds act as a blanket at night).



WIND

- Wind can influence variations in temperature and relative humidity.
- During the day, wind tends to disrupt surface heating by increasing mixing in the lower atmosphere. Wind mixes cooler air above the surface with air near the surface, which keeps temperatures cooler, and RH a little higher during the day.
- At night, wind tends to keep temperatures warmer and RH lower by disrupting radiative surface cooling. Wind helps prevent warm air from radiating away from the surface.



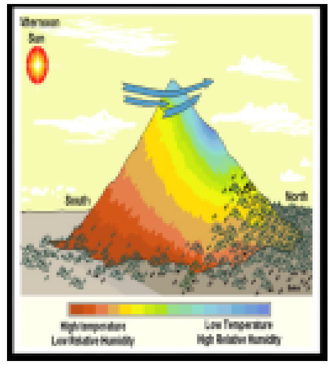
PROXIMITY TO BODIES OF WATER

Proximity to bodies of water can impact variations in temperature and RH.

- An increase in dew point and RH is likely to occur near a large body of water.
- Air over the Gulf of Mexico can move northward into northern latitudes during the winter months, increasing temperature over the land mass.

★ **QUESTION:** Stronger winds at night will:

A. Keep temperatures warmer and RH low.
B. Lower air temperature and raise RH.
C. Keep temperatures cooler and RH higher.



★ **QUESTION:** South-facing slopes are typically:

A. Cooler and drier than north-facing slopes.
B. Cooler and more moist than north-facing slopes.
C. Warmer and drier than north facing slopes.
D. Warmer and more moist than north-facing slopes.

★ **QUESTION:** Which of the following correctly explains cloud cover at night?

A. Keeps surface temperatures cooler than would otherwise be expected
B. Keeps surface temperatures warmer than would otherwise be expected

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ANSWER

Stronger winds at night will:

A. Keep temperatures warmer and RH low.

ANSWER VALIDATION

Winds at night keep the air mixed near the surface and disrupt radiant cooling (reduces the amount of heat that escapes through radiant cooling by mixing the air near the surface). Without winds or under calm conditions, radiant cooling processes are more effective, allowing heat to escape the surface (surface cooling).

ANSWER

South-facing slopes are typically:

B. Warmer and drier than north-facing slopes.

ANSWER VALIDATION

1. *South-facing slopes receive more incoming solar radiation than north-facing slopes. High sun angle in the afternoon allows for south-facing slopes to receive the longest period of incoming solar radiation during the hottest and driest time of the day (which promotes hotter temperatures and lower RH).*
2. *Different aspects represent different climate zones. If applicable, the instructor should reiterate differing fuel types from north aspect vs. south aspect.*

ANSWER

Which of the following correctly explains cloud cover at night?

C. Keeps surface temperatures warmer than would otherwise be expected.

ANSWER VALIDATION

Clouds at night act as a blanket, disrupting radiant cooling, thus keeping temperatures warmer, and RH lower.

END OF UNIT 3

Please review the objectives below and answer the questions on your Task Sheet that relate to Unit3.

Objectives

- Describe dry bulb temperature, wet bulb temperature, dew point, and relative humidity
- Describe how temperature and relative humidity can influence wildland fire behavior
- Determine relative humidity and dew point by using a Psychometric Table and given inputs

■ UNIT 4 Topography

Objectives

- Identify topographic features found in the wildland fire environment.
- Describe the basic characteristics of topography and how they can affect wildland fire behavior.

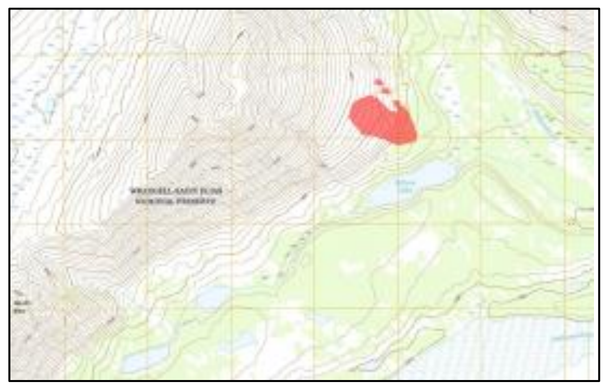
TOPOGRAPHY

- Topographic influences on wildland fire behavior are much easier to predict than the influences of fuel and weather.
- Topography can be broken up into two primary categories:
- Topographic Features: Canyons, ridges, chutes and saddles, and natural, or constructed barriers.
- Topographic Characteristics: Slope, aspect, and position on slope.

The arrangement of the natural and artificial physical features of an area.

TOPOGRAPHIC REPRESENTATIONS

- Topography has a direct effect on wildland fire behavior. Fire personnel use various tools to assess and gather information about the topography of an area.
- A topographic map is an example of the most common tool that provides a picture of the terrain and constructed features using contour lines, colors, and symbols.
- Contour lines represent the shape and elevation of the land, such as ridges, valleys, and hills.
- Colors and symbols are used to represent other features on the land, such as water, vegetation, roads, boundaries, urban areas, and structures.
- This unit references topographic maps and some of the basic information which can be derived from them. However, basic land navigation and map interpretation are not an intent of this unit or course.



For individuals who are interested, Basic Land Navigation, PMS 475, https://www.nwcg.gov/publications/475 is a self-study introduction to land navigation. It can be downloaded at no cost. Or hard copies can be ordered from the NWCG NFES Catalog – Part 2: Publications, PMS 449-2, https://www.nwcg.gov/publications/449-2.

WATCH VIDEO: How to Read a Topo Map (3:47)
Topographic maps are a little different from your average map. Once you get the hang of reading them, they help you visualize three-dimensional terrain from a flat piece of paper.

TOPOGRAPHIC FEATURES

Reference Look Up, Down and Around in the Incident Response Pocket Guide (IRPG), PMS 461, [*https://www.nwcg.gov/publications/461*](https://www.nwcg.gov/publications/461)

CANYONS

RIDGES

CHUTES & SADDLES

NATURAL AND CONSTRUCTED BARRIORS

NARROW CANYON

Fires starting in steep narrow canyons can easily spread to fuels on the opposite side due to radiant heating and spotting.

- Increases in wind and strong upslope air movement can be expected at sharp bends in the canyon.

BOX CANYON

Classified as a steep-sided, dead end canyon.

- Fires starting near the base of a box canyon can react similar to a fire in a fireplace. Air will be drawn in from the canyon bottom creating very strong upslope drafts.
- The upslope draft can create rapid fire spread up the canyon, also referred to as the chimney effect.

WIDE CANYON

Fire in a wide canyon can be heavily influenced by wind. Prevailing wind direction can be altered by the direction of the canyon.

- Cross-canyon spotting of fires is not common, except in high winds.
- Drastic differences in fire behavior will occur on north or south aspects of the canyon

RIDGES

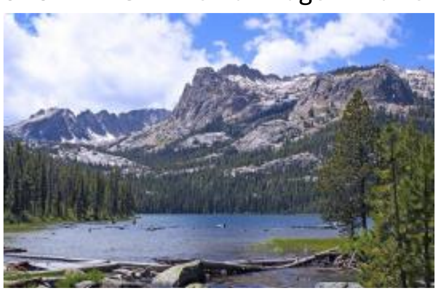
A long narrow elevation of land; a steep slope or a similar range of hills or mountains.

- A ridge is a common topographic feature typically consisting of a long high area that slopes down to two different aspects on either side.
- Reference the following four types of ridges in describing the predominate topographic features of an area:
  - Dominant
  - Spur
  - Flat
  - Knife

- **TYPES OF RIDGES**

  DOMINANT - Forms a prominent skyline feature; may have one or more spur ridges that connect to it

SPUR RIDGE - A small ridge which extends finger-like from a main ridge



FLAT RIDGE - Has terrain that slopes down gently from one or both sides of the ridgeline. Often make good places for fire containment because of easier travel along the ridge and moderate fire behavior.

KNIFE RIDGE - Has steep slopes that extend down both sides of the ridgeline.

RIDGE INFLUENCE ON FIRE BEHAVIOR

Ridges may offer a good place to assist in containing a fire**.**

- When fires reach a ridgeline, the rate of spread often slows as it encounters an opposing upslope airflow from the other side of the ridge.
- This effect can slow the fire spread and limit spotting concerns on the opposite slope.
- However, the effect of erratic winds caused by various winds converging at the ridgetop can change fire behavior. This is especially likely if the winds on one side of the ridge are stronger than the other.

TOPOGRAPHIC MAP REPRESENTATION OF A RIDGE

At a quick glance, what information can the map provide about this ridge?

QUESTION:

At a quick glance, what information can the map provide about the ridge?

Answer: It is a named landmark feature (Pony Ridge), so it can be used as a point of reference.

Answer: It provides information on the shape and elevation of the area.

Answer: Colors provide information on the predominate vegetation cover; green shading indicates woodland.

QUESTION:

How would fire personnel benefit from obtaining information on the fuel availability?

Answer: Terrain indicates a baseline on the quantity of fuel available for combustion based on slope, aspect, and other terrain features.

SADDLES

Depression or pass in a ridgeline.

- Wind blowing through a chute or saddle can increase in speed as it passes through the constricted area and spreads out on the downwind side.
- The effect on fire behavior can lead to a change in direction and an accelerated rate of spread.
- This effect is similar to the chimney effect associated with box canyons.

CHUTES

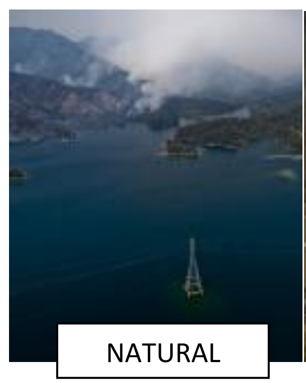
Fairly narrow and straight depressions that lead up a ridgeline.

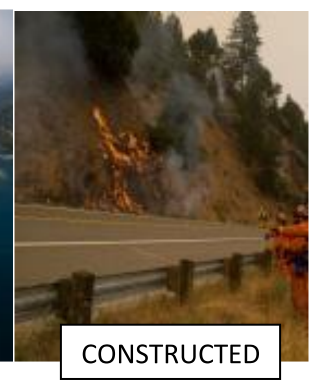
- Wind blowing through a chute or saddle can increase in speed as it passes through the constricted area and spreads out on the downwind side.
- The effect on fire behavior can lead to a change in direction and an accelerated rate of spread.
- This effect is similar to the chimney effect associated with box canyons.

NATURAL AND CONSTRUCTED BARRIERS

A barrier is any obstruction to the spread of fire, typically an area or strip devoid of combustible fuel.

- Barriers to fire may include both natural or constructed types.
  - Natural barriers include: Rivers. Lakes. Rocks. Rockslides.
  - Constructed Barriers include: Roads. Highways. Reservoirs.
- Most barriers are effective at limiting or slowing surface fire spread. Containment lines created by firefighters are classified a constructed barrier.





TOPOGRAPHIC MAP REPRESENTATION OF A BARRIER

QUESTION:

At a quick glance, what information can the map provide about the barrier?

Answer:

It is a named landmark feature (Salmon River), so it can be used as a point of reference. Answer: It provides information on the shape and elevation of the area.

TOPOGRAPHIC CHARATERISTICS

SLOPE

ASPECT

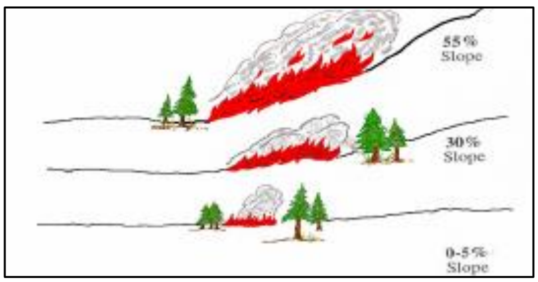
POSITION ON SLOPE

- Have direct influence on fuel temperature and moisture.
- The characteristics presented in this unit are:
    - Slope
    - Aspect
    - Position on slope

- **TYPES OF CHARACTERISTICS**

SLOPE - The amount or degree of incline on a hillside. The slope of a hill side is what is referred to when describing how steep it is. It can affect the amount of fuel available.

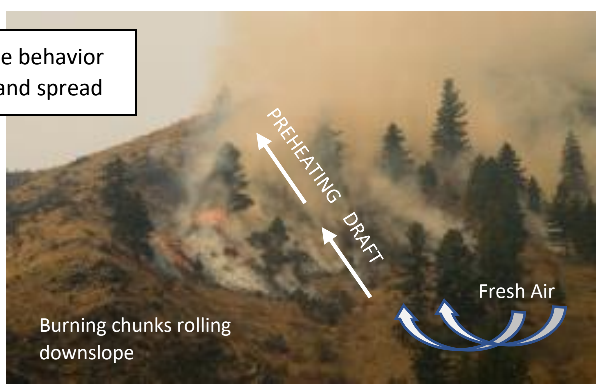
The ratio between the amount of vertical rise of a slope and horizontal distance as expressed in a percent. One hundred feet of rise to 100 feet of horizontal distance equals 100 %.



- For example, a highway sign in a mountainous area may say 6% grade ahead. This indicates that for every 100 feet you travel, you will gain, or lose 6 feet in elevation.
- A fire at the 0-5% slope range is primary influenced by wind and fuel arrangement. It typically develops and spreads at a slower rate.
- A fire at the 30% slope range has the potential to develop and spread uphill at a faster rate.

SLOPE AND RATE OF SPREAD

Slope affects fire behavior
Faster ignition and spread



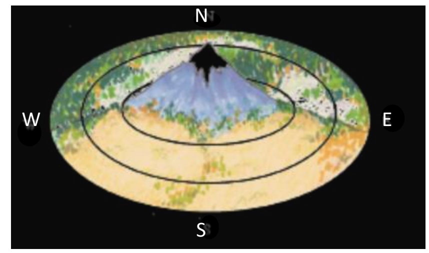
Rate of Spread – The relative activity of a fire in extending its horizontal dimensions. Usually it is expressed in chains or acres per hour for a specific period in the fire's history.

- A visual example of a fire developing in the 30% slope range and the slope's effect on rate of spread.
- Fires move at a faster rate of spread uphill than downhill; therefore, the steeper the slope, the faster the rate of spread.
- Convective and radiant heating are key factors in this rate of spread. The fuels above the fire are brought into closer proximity with the progressing fire, drying out, or preheating the fuels ahead of the approaching fire, making them more receptive to ignition, and increasing rate of spread.
- Another concern with steep slopes is the possibility of burning material rolling down the hill and igniting fuel below the main fire.
- Although fires typically burn slower down slope, a downslope wind can impact rate of spread and create what is referred to as a downhill run.
- Slope reversal can lead to dramatic changes in fire behavior. When a fire burning downslope reaches the bottom and begins burning uphill on the opposite aspect, fire behavior is likely to increase.

ASPECT - Cardinal direction toward which a slope faces.

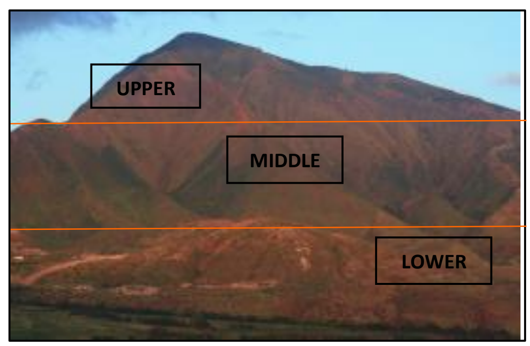
- The aspect of a slope determines the amount of heating it gets from the sun. Therefore, it influences the fuel on that slope.
- Aspect is described by using the cardinal direction (north, east, south, west) the slope is facing.
- Discuss the drastic difference in fuel on the different aspects shown in the image.

INFLUENCE OF ASPECT



- South and southwest slopes are the most critical in terms of start and spread of wildland fires.
- South and southwest slopes are exposed to more sunlight and typically have:
  - o Lighter and sparser fuels
  - o Higher temperatures
  - o Lower humidity
  - o Lower fuel moisture
- North facing slopes have more shade which causes:
  - o Heavier fuels
  - o Lower temperature.
  - o Higher humidity
  - o Higher fuel moistures

POSITION ON SLOPE



- Position on slope is a way to describe the relative location of something on the hillside.
- It is common to hear the terms lower, middle, and upper as a way to describe the location.

- Position on slope corresponds with elevation in determining type, conditions, and amount of fuel.
- Position on slope is directly related to:
  - o Types of fuels.
  - o Moisture levels.
  - o Wind exposure.
  - o Temperature.
- Fuels at a lower position on slope and at a lower elevation will dry out and be receptive to ignition and spread faster than fuels positioned higher on the slope.

END OF UNIT 4

Please review the objectives below and answer the questions on your Task Sheet that relate to Unit4.

Objectives

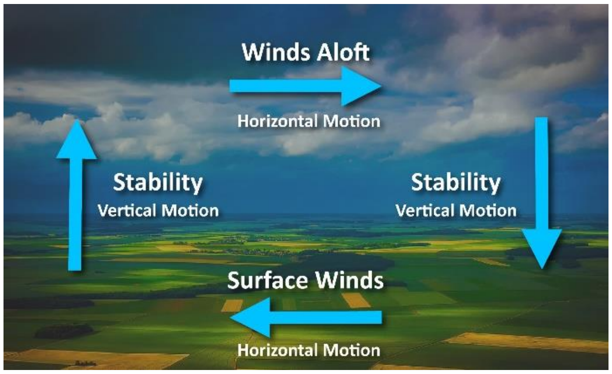
- Identify topographic features found in the wildland fire environment.
- Describe the basic characteristics of topography and how they can affect wildland fire behavior.

UNIT 5 Atmospheric Stability. Winds. Clouds

Objectives

- Describe atmospheric stability and discuss the effects on fire behavior.
- Describe wind and its effects on fire behavior.
- Explain cloud classifications and their impact on fire behavior.
- Explain the similarities between smoke layers and clouds in relation to impact on fire behavior.

WATCH VIDEO: Introduction to Atmospheric Stability (00:45)
Introduces the way atmospheric stability can affect wildland fire.



ATMOSPHERIC STABILITY

The degree to which vertical motion in the atmosphere is either enhanced or suppressed.

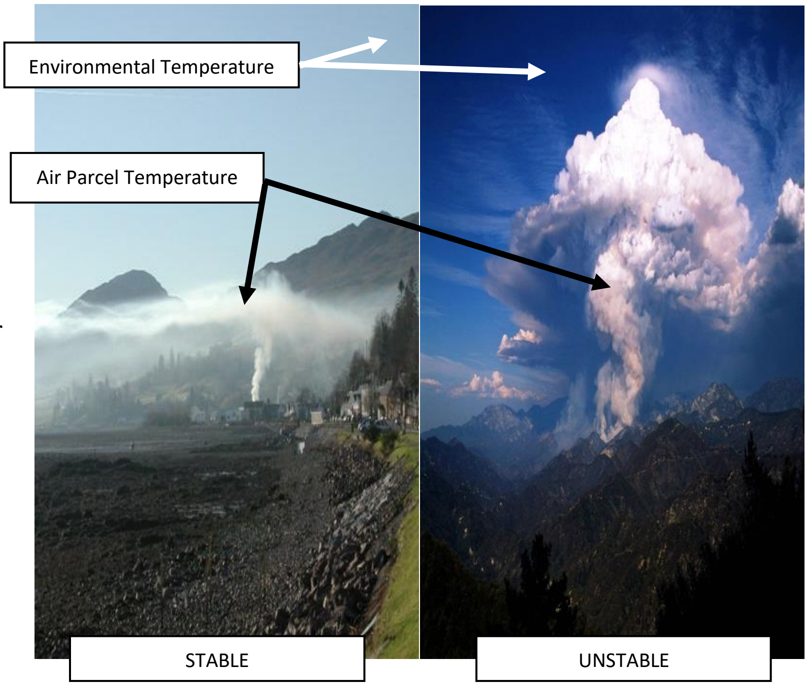
- Environmental temperature structure of the atmosphere determines whether the atmosphere will enhance or suppress vertical motion.

EXAMPLE OF ATMOSPHERIC STABILITY

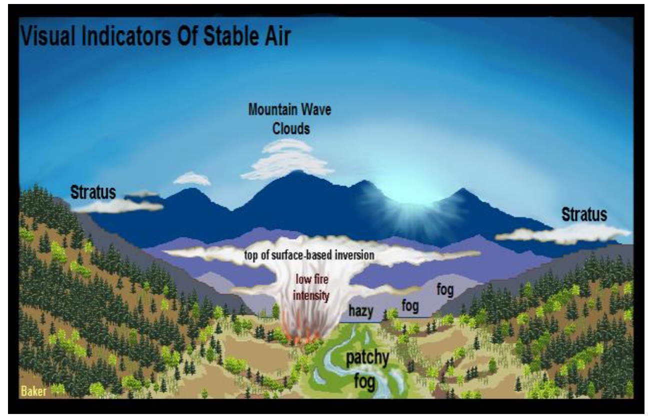
- Hot air inside the balloon is less dense than the environmental air outside, causing the balloon to rise.
- As temperatures warm, the density of the environmental air rises, air in the balloon becomes less dense in comparison, and the balloon descends.
- When heated, air parcels become less dense and rise in the atmosphere.
- Using a hot air balloon as an example helps firefighters grasp the basic concepts of atmospheric stability. The hot air balloon can be thought of as an air parcel.
-

DETERMINING ATMOSPHERIC STABILITY

- Atmospheric stability is determined by comparing the temperature of an air parcel or smoke column to the environmental temperature – the air temperature outside the parcel or smoke column.
- Stable: If the parel temperature is equal to or cooler than the environmental temperature, it will stay at its current level or sink.
- Unstable: If the air parcel temperature is warmer than the environmental temperature, it will rise.
- Reference Haines Index (HI) in the *Incident Response Pocket Guide (IRPG)* https://www.nwcg.gov/publications/461.

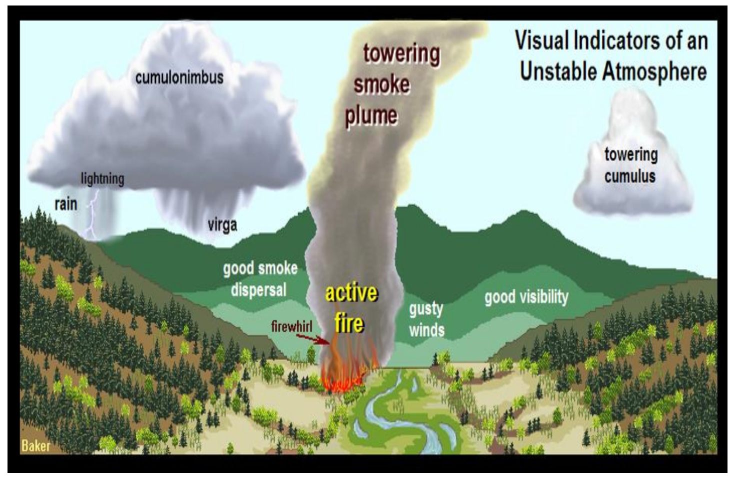


STABLE ATMOSPHERIC INDICATORS



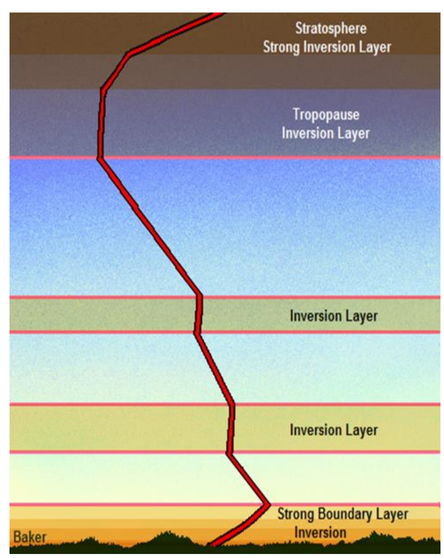
- Visual indicators of stable atmospheric conditions:
    - Smoke layer.
    - Stratus clouds or fog.
    - Low intensity fire as a result of suppressed vertical motion and weak inflow wind to feed fire new oxygenated air.
    - Mountain wave clouds occur, which indicate strong winds aloft that could surface on the lee side of a mountain range that day.
- Effects of stable atmospheric conditions on fire behavior:
    - Limited rise of smoke columns, resulting in poor smoke dispersion and visibility.
    - Reduced inflow of fresh air, thereby limiting fire growth, and intensity.
    - Lower surface wind speeds and fire spread rates, except in mountainous, and hilly terrain – refers to foehn winds.

STABLE ATMOSPHERIC INDICATORS



- Visual indicators of unstable atmospheric conditions:
    - Towering smoke plume.
    - Cumulus clouds – these are from rising air parcels.
    - Cumulonimbus clouds – these are from rising air parcels.
    - High intensity fire as a result of increased vertical motion and sufficient, sometimes intense, inflow wind feeding the fire new oxygenated air.
    - Gusty winds – a result from mixing of the lower atmosphere.
    - Good visibility.
- Effects of unstable atmospheric conditions on fire behavior:
    - Increased likelihood of fire whirls and dust devils.
    - Increased likelihood for gusty and erratic surface winds.
    - The height and strength of convection and smoke columns often increase significantly.
    - Increased likelihood of fire brands being lifted to great heights.

ATMOSPHERIC TEMPERATURE AND INVERSIONS



An inversion is a layer of very stable air. An inversion acts like a cap or lid to severely limit the upward movement of air.

- Warm layers exist at different levels of the atmosphere. Meteorologists use weather data and atmospheric models to determine the strength and level of the inversions.
- Once the level and strength of the inversion is measured and analyzed, the meteorologist can determine the impacts on the fire environment.

WATCH VIDEO: Temperature Inversions (2:20) ***Must watch video in the PowerPoint***
Mist and fog, hazy horizons, layers of cloud and even persistent rain or drizzle can often be caused by temperature inversions. But what are temperature inversions and how do they form?

WATCH VIDEO: Atmospheric Temperature and Inversions (00:08) ***Must watch video in the PowerPoint***
You will need to a media player to view, No Audio.
Time-lapse of a valley with an inversion filling the valley floor. The inversion is preventing upward vertical motion, indicated by the fog layer.
PRIOR TO WATCHING:
Think about the following when watching the video:

- The video shows an inversion that is preventing upward vertical motion, noted by the fog layer.
- Surface heating or temperature changes above the inversion can erode and break the inversion.
- Heat from fire activity can erode and break the low-level inversion.

RECOGNIZING A DEVELOPING INVERSION

- Stable conditions develop
- Surface temperatures decrease
- Relative humidity increases
- Winds may become light
- Smoke flattens after limited rise (layers)
- Fire behavior typically decreases

WATCH VIDEO: [Recognizing a Dissipating Inversion] (00:25) *You will need to a media player to view, No Audio.*
Time-lapse of a valley with an inversion leaving the valley floor.
PRIOR TO WATCHING:
Reference Look Up, Down and Around in the *Incident Response Pocket Guide (IRPG)*, PMS 461, https://www.nwcg.gov/publications/461 while watching and after the video.

Think about the following when watching the video:

- Wind may increase and change direction.
- Temperature increases and relative humidity decreases.
- The air mass becomes unstable (changing smoke behavior).
- Smoke begins to loft and develop a column.
- Fire behavior increases.

WIND

The horizontal movement of air relative to the surface of the earth.
Importance of wind and its impact on fire behavior:

- Most critical factor affecting fire behavior.
- Difficult to predict, especially in complex terrain.
- Most variable in time and space.
- Poses safety and control problems but can support tactics if accurately measured and forecasted.

WATCH VIDEO: Wind (1:04) ***Must watch video in the PowerPoint***
Introduction to wind and its effect on the fire environment.
Reference Important Winds to Firefighters in the *Incident Response Pocket Guide (IRPG)*, PMS 461, https://www.nwcg.gov/publications/461.

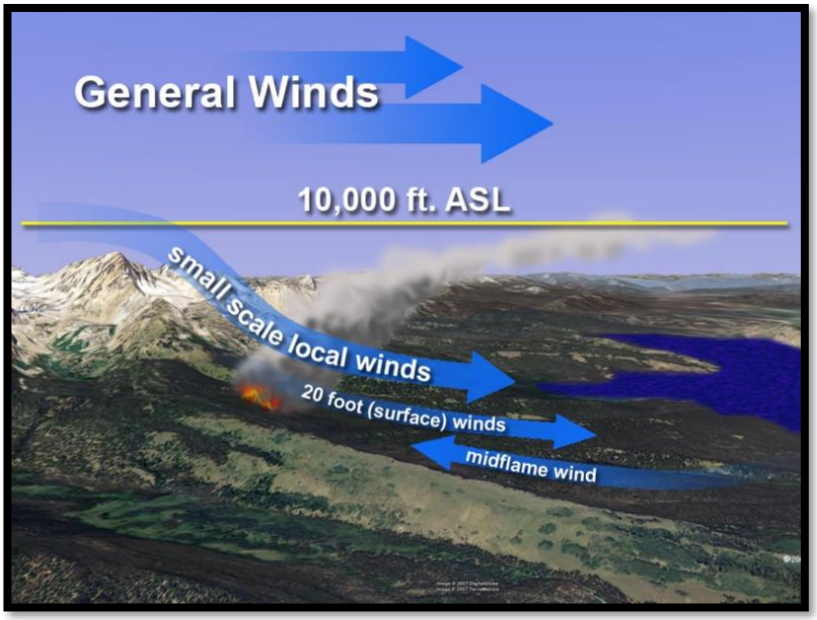
WIND DIRECTION
Compass direction from which wind is blowing.

QUESTION:
A northeast wind is coming from what direction?

ANSWER:
The northeast

GENERAL WINDS
Large scale winds caused by high- and low-pressure systems but generally influenced and modified in the lower atmosphere by terrain.

- Winds driven by large scale high- and low pressure systems.
- Winds typically found at mid- and upper-levels of the troposphere.
- Winds responsible for transporting weather systems around the world.



WATCH VIDEO: General Winds (0:16) ***Must watch video in the PowerPoint***
Time-lapse of a fire and the sky above showing the impact of general winds. *Impact of General Winds on Fire Behavior.*

LOCAL WINDS

Winds which are generated over a comparatively small area by local terrain and weather. They differ from those which would be appropriate to the general pressure pattern.

WATCH VIDEO: Local Winds (0:16) ***Must watch video in the PowerPoint***

Time-lapse of fire on a mountain side and the effects of local winds on the fire.

PRIOR TO WATCHING

Think about the following when watching the video:

- Winds found at lower levels of the troposphere.
- Induced by small-scale differences in air temperature and pressure.
- Influenced by terrain; the more varied the terrain, the greater the influence.
- Influenced by the difference in sea and land surface temperatures.
- Local winds may be the only wind impacting a fire, or it could be a combination of general and local winds.

DOWNSLOPE AND DOWN-VALLEY WINDS

Downslope wind speeds range from 2-5 mph. Down-valley wind speeds range from 5-10 mph.

- Small-scale convective winds that occur due to local heating and cooling of a natural incline of the ground.
- A result of slopes or valleys cooling at night. The cooler air will sink down a slope or valley.

WATCH VIDEO: Downslope and Down Valley Winds (0:21) ***Must watch video in the PowerPoint***

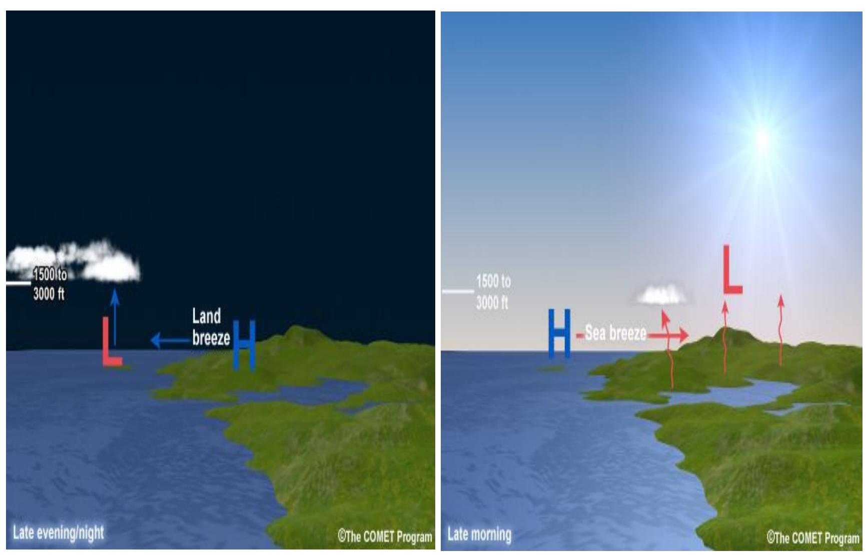
Animation of a valley at night with a fire on a nearby slope and arrows showing the movement of air.

PRIOR TO WATCHING:

Think about the following when watching the video:

- Small-scale convective winds that occur due to local heating and cooling of a natural incline of the ground.
- A result of slopes or valleys cooling at night. The cooler air will sink down a slope or valley.

LAND AND SEA BREEZES



- Land and sea breezes are common winds in coastal regions. Firefighters should anticipate wind shifts when working near large bodies of water (lake or ocean).
- Land Breeze: During the evening and overnight hours, the land mass becomes cooler than the air over the large body of water. Air over the land becomes stable and the air over the body of water becomes unstable. The rising air over the water is replaced by the air over the land.
- Sea Breeze: During the late morning and early afternoon, the land mass becomes warmer than the air over the large body of water. Air over the land becomes unstable and rises (low pressure). The rising air over the land is replaced by the air over the body of water.

MID-FLAME WIND EFFECTS ON FLAME HEIGHT

Reference Beaufort Scale in the *Incident Response Pocket Guide (IRPG)* https://www.nwcg.gov/publications/461.

- General or local winds, or components of both, contribute to wind speed and direction, including 20-foot and mid-flame winds.
- Mid-flame wind is the wind that acts directly on the flaming fire front at the level of half the flame height. An excellent approximation of the mid-flame wind is the eye-level wind.
- Eye-level wind can be measured by the firefighter with
  the Belt Weather Kit wind meter or a handheld electronic weather meter.

WIND EFFECTS ON FIRE BEHAVIOR

- Wind carries away moisture-laden air and hastens the drying of wildland fuels.
- Once a fire ignites, wind aids combustion by increasing the supply of oxygen.
- Wind increases fire spread by carrying heat and burning embers to new fuels (spotting).
- Wind bends the flames closer to the unburned fuels, pre-heating the fuels ahead of the fire front.
- Changes in wind direction and speed can rapidly change fire behavior from inactive to active.
- The direction of the fire spread and smoke transport are determined mostly by wind direction.

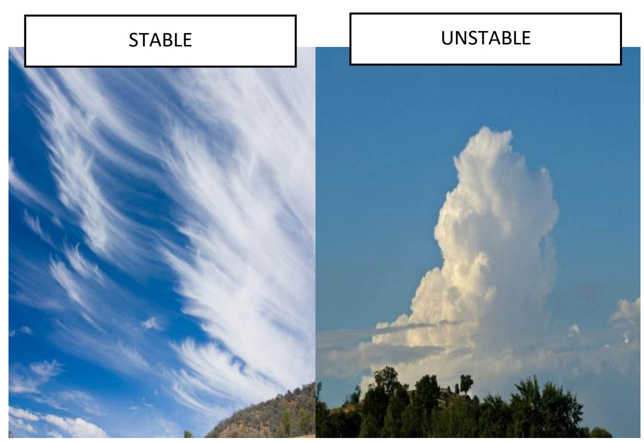
WATCH VIDEO: Wind Effects on Fire Behavior (0:17) ***Must watch video in the PowerPoint***
Time-lapse of wildfires on varying landscapes and the effects of wind on fire behavior.

CLOUDS

A visible collection of moisture suspended in the atmosphere.

- Clouds form under stable or unstable atmospheric conditions, and not all clouds produce precipitation.
- There are numerous cloud types. This course only covers some of the basic, important clouds to firefighters.

- **WATCH VIDEO:** Clouds (0:39) *You will need to a media player to view.*
  Introduction to how clouds can change fire behavior.
  PRIOR TO WATCHING:
  Reference Look Up, Down and Around in the *Incident Response Pocket Guide (IRPG)*, PMS 461 https://www.nwcg.gov/publications/461.



CLOUD IMPACTS ON FIRE ENVIRONMENT

Clouds can modify the fire environment by changing:

- Temperature
- Relative Humidity
- Atmospheric Stability
- Wind
- Fuel Temperature
- Fuel Moisture
- Fire Behavior

WATCH VIDEO: Campfire (0:17) ***Must watch video in the PowerPoint***

An animation of a campfire burning and clouds moving in, creating cooler temperatures.

PRIOR TO WATCHING:

Think about the following when watching the video:

- Clouds can reflect incoming solar radiation and, therefore, affect fire weather conditions by:
  - Creating cooler temperatures.
  - Increasing relative humidity.
  - Changing wind and stability.
- Changes in fire weather conditions directly impact:
  - Fuel moisture.
  - Decreases in fire behavior.

CLOUD CLASSIFICATION

- Clouds are classified by height.
- High: 6,000-50,000 feet. Usually pure white in color and made up of ice crystals.
- Middle: 6,500-23,000 feet. Usually a combination of white and gray in color and made of water droplets and ice crystals.
- Low: 0-6,500 feet. Usually gray in color and made of water droplets.

Refer to the *The Fire Weather Cloud Chart*, PMS 438, https://www.nwcg.gov/publications/438

Find the clouds on the chart that are of critical concern for firefighters are outlined in RED boxes.

★ Write down the definitions for the following clouds:

Altocumulus Castellanus

Cumulonimbus

Mature Thunderstorm

VERTICALLY DEVELOPED CLOUDS

- Made up of water and ice and indicate unstable atmospheric conditions.
- An unstable atmosphere can result in an increase in fire behavior. Identifying this type of cloud is important when predicting changes to the fire environment.
- Cumulus clouds could result in cumulonimbus clouds (thunderstorms), which could result in gusty and erratic winds.
- Bases can range from 1,500 to 10,000 feet, depending on air mass conditions in different parts of the country.
- For example, cumulus clouds or thunderstorms typically have higher bases compared to the same cloud types in southern and eastern sections of the United States.

WATCH VIDEO: Vertically Developed Clouds (0:14) ***Must watch video in the PowerPoint***
Time-lapse of cumulus cloud being formed over land.

PRIOR TO WATCHING:

Think about the following when watching the video:

- Made up of water and ice and indicate unstable atmospheric conditions.
- An unstable atmosphere can result in an increase in fire behavior. Identifying this type of cloud is important when predicting changes to the fire environment.
- Cumulus clouds could result in cumulonimbus clouds (thunderstorms), which could result in gusty and erratic winds.
- Bases can range from 1,500 to 10,000 feet, depending on air mass conditions in different parts of the country.
- For example, cumulus clouds or thunderstorms typically have higher bases compared to the same cloud types in southern and eastern sections of the United States.

SMOKE LAYERS

Smoke layers mimic clouds in modifying the fire environment by changing:

- Temperature
- Relative Humidity
- Atmosph eric Stability
- Wind
- Fuel Temperature
- Fuel Moisture
- Fire Behavior

QUESTIONS?

Stable - OR - Unstable?

1 Clouds or smoke columns that grow vertically indicate a(n) _________ atmosphere.

2 A smoke column that spreads out after limited rise indicates a(n) _______ atmosphere.

Fill in the blanks:

3 Wind direction is the direction _______ which the wind is blowing.
4 General wind is a ______ scale wind associated with high and low pressure.
5 Local wind is a ______ scale wind.
6 True or False. Wind is the most critical factor affecting fire behavior.
7 The direction of the fire spread and smoke transport are mostly determined by _______.

Refer to the picture to answer questions below →

8 Does this type of cloud indicate a stable or unstable atmosphere?

9 What fire behavior can be anticipated?

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ANSWERS

1 Unstable

2 Stable

3 from

4 large

5 small

6 true

7 direction of wind

8 unstable atmosphere

9 increase in fire behavior

END OF UNIT 5

Please review the objectives below and answer the questions on your Task Sheet that relate to Unit5.

Objectives

- Describe atmospheric stability and discuss the effects on fire behavior.
- Describe wind and its effects on fire behavior.
- Explain cloud classifications and their impact on fire behavior.
- Explain the similarities between smoke layers and clouds in relation to impact on fire behavior.

UNIT 6 Critical Fire Weather

Objectives

- Describe critical fire weather conditions.
- Describe critical fire weather events such as cold fronts, thunderstorms, foehn winds, and other local phenomenon that can impact fire behavior.

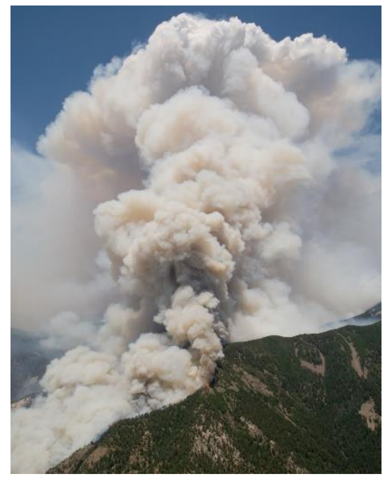
WATCH VIDEO: Critical Fire Weather (1:08) ***Must watch video in the PowerPoint***
Description of how geographic area, time of year, and weather contribute to critical fire weather patterns.

CRITICAL FIRE WEATHER

These weather factors, combined with receptive fuels, may result in extreme fire behavior:

- Dry Lightning
- Strong & Shifting Winds
- Warm Temperatures
- Low Relative Humidity
- Unstable Atmosphere

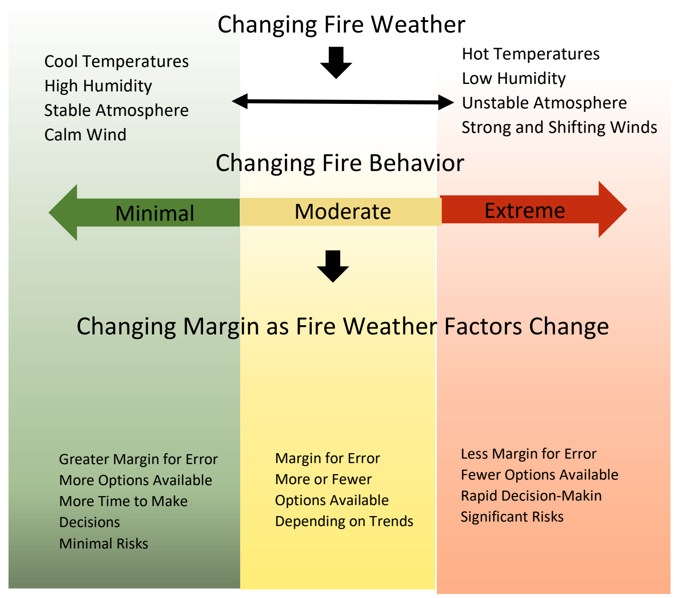
If fuels are receptive, an interaction with critical fire weather factors can result in extreme fire behavior.



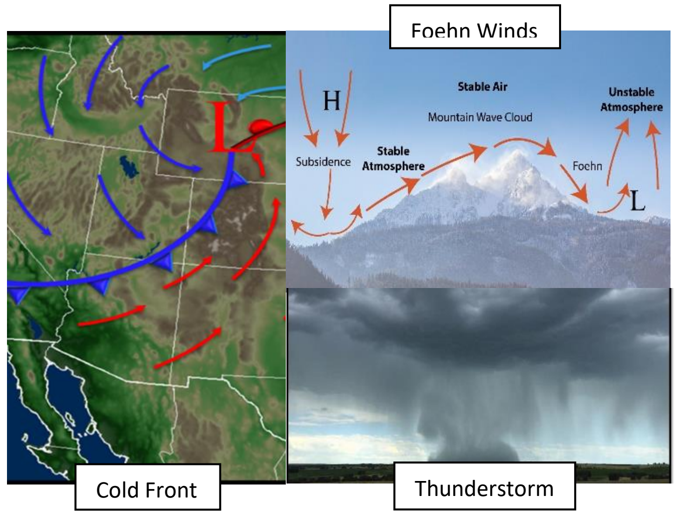
Reference Lightning Activity Level (LAL) in the Incident Response Pocket Guide (IRPG)
https://nwcg.gov/publications/461

CHANGING OF FIRE WEATHER FACTORS

- It's important to recognize that changing fire weather conditions can result in changes in the environment and fire behavior.
- As changes occur in the fire environment, so does the margin of error for adapting and reacting to those changes.
- Firefighters should be aware of changing weather conditions from morning to afternoon, some of which may be extreme:
  - For example, cool temperatures, high humidity, a stable atmosphere, and calm winds may be present in the morning, but hot temperatures, low humidity, an unstable atmosphere, and strong winds may come ahead of a cold front in the afternoon.
    In this example, the margin for error will decrease during the day as fewer options and less time cause rapid decision-making and a significant increase in risks.



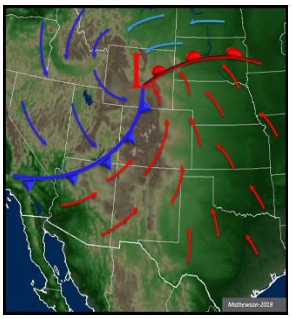
EXAMPLES OF WEATHER PHENOMENA
Characteristics of these phenomena relative to the local area where the course is being presented.



Reference the Common Denominators of Fire Behavior on Tragedy Fires in the Incident Response Pocket Guide (IRPG) *https://www.nwcg.gov/publications/461*

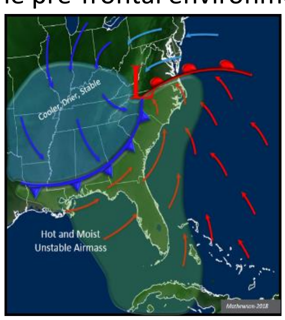
- **FRONT**
  There are different types of fronts. This course will focus on the cold front and its impacts on the fire environment.

  - **COLD FRONT**
    The cold front, symbolized by a blue line with triangles, represents the leading edge of a relatively cold or cooler air mass.



- An approaching cold front can quickly change the fire environment by producing:
  - Strong and shifting winds.
  - Warm and sometimes dry air mass.
  - Unstable conditions.
- Historically, firefighter fatalities have occurred during a pre-frontal environment where winds are strong and shifting and the atmosphere is unstable.

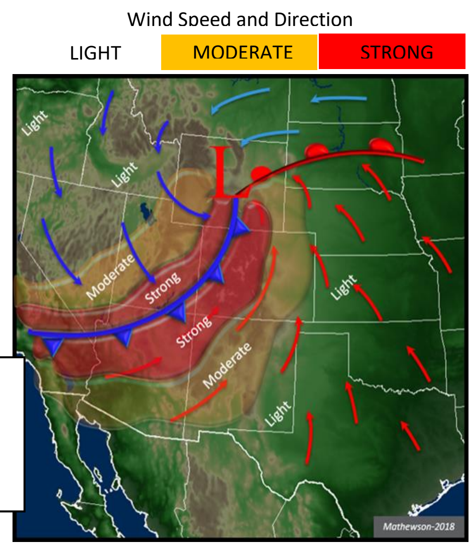
  - **PRE-FRONTAL ENVIRONMENT**
    Air mass conditions in the pre-frontal environment can differ based on geographic area.



Common post-frontal air mass conditions:

- Air mass behind the front tends to be more stable than the air mass ahead of the cold front.
- Temperatures are cooler.
- Relative humidity is higher.

  - **THE COLD FRONT**
    May promote strong and shifting winds, especially along the frontal boundary.
    - Winds associated with the passage of a cold front are dangerous, due to the strength of the wind and shift in wind direction as the front approaches and passes through the area.
    - These strong and shifting winds occur along the frontal boundary and are a result of a strong pressure/temperature gradient between the different air masses.



In addition to changes in **temperature, relative humidity, and atmospheric stability,** the approaching **cold front** typically results in:

STRONG & SHIFTING WINDS

WATCH VIDEO: Cold Front Passage and Fire Spread (0:08) ***Must watch video in the PowerPoint***
Animation of a cold front moving toward a fire and shifting the wind from northeast to southwest.

PRIOR TO WATCHING:
Think about the following when watching the video:
What to expect from a cold front passage:

- 150 miles ahead of the front
  - Wind is usually light and from the southeast direction.
  - Fire behavior may be active in this environment but predictable.
- 50-100 miles ahead of the front
  - As the front approaches, wind speed increases, and shifts from the southwest.
  - Wind speed may range from 15 to 30 mph, but could be stronger.
  - Fire behavior could significantly increase.
- Frontal Passage
  - Wind typically shifts northwest but remains strong (15 to 30 mph) until the front pushes further east.
  - Expect a gradual decrease in fire behavior as temperature decrease and relative humidity increases.

SCENARIO
It's March and you've been deployed to the State-Line Fire along the border of Colorado and New Mexico. Your crew has been briefed that a cold front is predicted to arrive in the fire area at around 1400.

WATCH VIDEO: Cold Front Scenario (0:03) ***Must watch video in the PowerPoint***
Animation of a weather map showing a cold front moving over the western states.

QUESTIONS?

1 What are the typical trends in temperature and relative humidity between 1400 and 1700?

2 How does wind-speed change as a front approaches?

3 What are the typical changes in fire behavior between 1400 and 1700?

4 What are some common trends in weather and fire behavior after a front moves through?

ANSWERS

1. ***Increase in temperatures and a decrease in relative humidity.***
2. ***Wind increases as the front approaches.***
3. ***Fire behavior typically increases.***
4. ***Decrease in temperature and increase in relative humidity.***
   Winds will shift, but remain strong until the front moves on.
   Fire behavior will gradually decrease.

- **CUMULONIMBUS (THUNDERSTORM)**
  A localized storm characterized by lightning and gusty erratic outflow wind.
  - Unstable atmosphere.
  - Can occur in a moist and dry air mass environments.
  - In-draft wind speeds range from 10 to 20 mph.
  - Outflow wind speeds range from 25 to 35 mph with gusts over 60 mph.
  - Thunderstorms are usually of short duration, seldom more than 2 to 3 hours.
  - The direction of thunderstorm movement is generally in the direction of the winds aloft.
  - The direction of movement can be determined by the direction the anvil shaped top is pointing.

Reference Thunderstorm Safety in the Incident Response Pocket Guide (IRPG)
https://www.nwcg.gov/publications/461.

WATCH VIDEO: Thunderstorm Characteristics (0:49) ***Must watch video in the PowerPoint***
Time lapse of a thunderstorm moving over a valley.

PRIOR TO WATCHING:

Think about the following when watching the video:

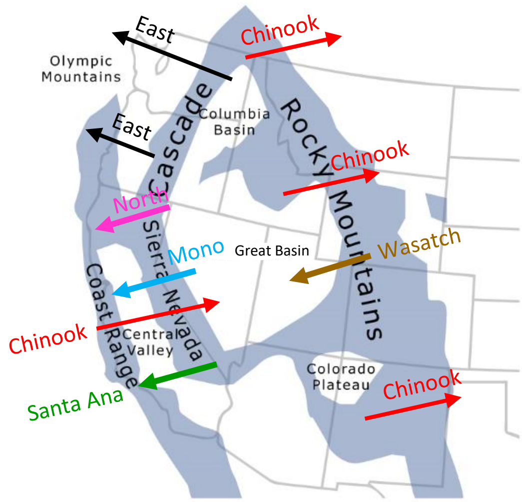
- Characteristics of a thunderstorm can include:
  - Strong winds
  - Heavy rain
  - Hail
- Downdrafts are a primary concern.
  - The winds generated by a downdraft reach the ground and spread radially in all directions.
  - Downdraft wind velocities will often be 25 to 35 mph and can reach as high as 70 mph.

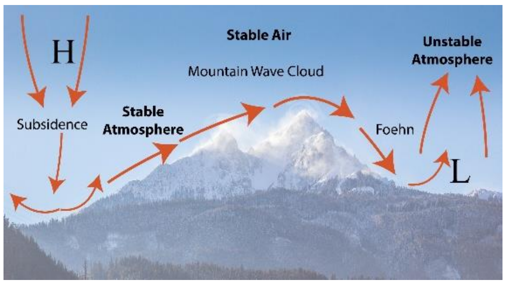
DOWN DRAFT INDICATORS

- Virga is precipitation falling out of a cloud but evaporating before reaching the ground.
- A rain shaft is a dark vertical shaft of heavy rain, localized over a small area. Unlike virga, the precipitation reaches the ground.
- Dust clouds are a result of an incoming front stirring up the sediment from the ground and creating a dust cloud that will travel in front of the incoming front.
- As a front moves in, if rain drops are felt, the downdraft has begun.

FOEHN WINDS *Most commonly pronounced like "fern"*

- Strong, dry winds caused by the compression of air as it flows down the lee side of a mountain range.
- The names of the most common vary from one location to the next. The Santa Ana winds are one of the more famous winds, producing extreme fire behavior in southern California.
- Foehn winds can persist for days and frequently reach speeds of 40 to 60 mph but can be as high as 90 mph.
- Relative humidity will usually drop with the arrival of foehn winds.
- The combination of high wind speeds and low relative humidity can cause high rates of fire spread.





FOEHN WIND CHARACTERISTICS

★ **QUESTION:**

What causes air to move down the lee side of the mountain range?

ANSWERS:

1 *Foehn winds occur under high pressure and stable conditions.*

2 *The air parcel on the windward side of the mountain range is forced up to the top of the ridge.*

3 *When the air gets to the top of the ridge, it wants to return back to its original elevation and does so on the lee side of the mountain.*

4 *The air quickly moves down the slope at speeds ranging from 40 to 60 mph (strong wind).*

- **WATCH VIDEO:** Foehn Wind Indicator (0:09) ***Must watch video in the PowerPoint***

  Time lapse of clouds indicating foehn winds.

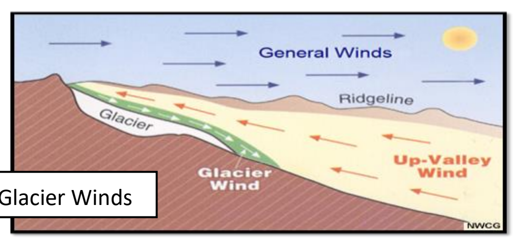
  PRIOR TO WATCHING:

  Think about the following when watching the video:

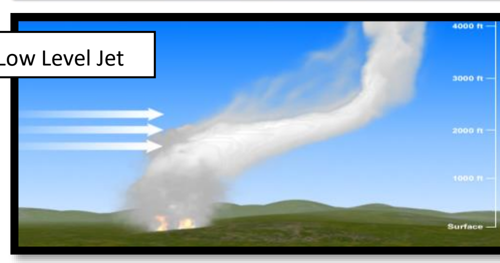
  - Wave Clouds (Altocumulus Standing Lenticular) are indicators of a foehn wind event occurring.

LOCALIZED CRITICAL FIRE WEATHER EVENTS

- In addition to foehn winds, there are other localized weather events that occur in different regions or geographic areas that can impact wildland fire behavior.
- Glacier Winds – can be experienced in the spring across the west where snowpack and snow fields linger over the higher elevations. Strong, shifting winds are characteristic of glacier or snow fields.
- Low Level Jet – a region of relatively strong winds in the lower part of the atmosphere commonly found across the plains at night.



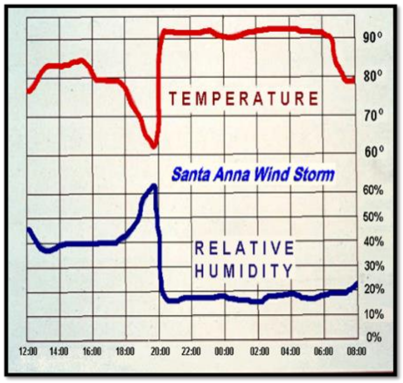
Glacier Winds



Low Level Jet

QUESTION? Foehn Wind Scenario

On October 7, 1971, shortly after the change from day shift to night shift on the Romero Fire, "intensity picked up".



Based on the changes in temperature and RH around 2000, what occurred at that time that to cause the increase in fire behavior?

ANSWERS:

1 *A Santa Ana foehn wind storm occurred at around 2000.*

2 *In a period of about 15 minutes, temperatures increased by 30° and RH dropped by about 50%, from 60 to 15.*

3 *Because of the general characteristics of foehn winds, this change in temperature, and RH was most likely accompanied by a strong downslope wind.*

WATCH VIDEO: Pyro-Cumulus (0:30) ***Must watch video in the PowerPoint***

Time lapse of pyro-cumulus development.

PRIOR TO WATCHING:

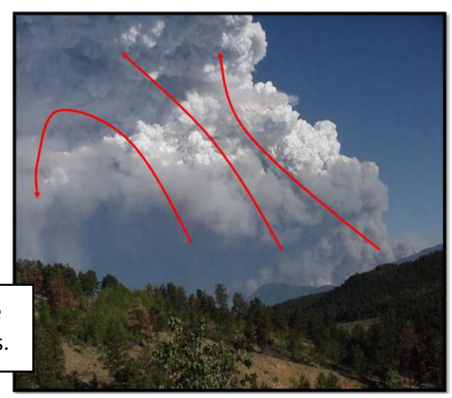
Think about the following when watching the video:

- A phenomena that can be generated from large wildfires. The intense heating of the air caused by wildfires induces convection and causes the air mass to rise.
- If the fire grows large enough, the pyro-cumulus cloud may continue to grow and can develop into a type of cumulonimbus cloud (thunderstorm).
- The development into a thunderstorm can generate lightning. When this occurs, the smoke column is generating its own weather.

PYRO-CUMULONIMBUS FORMATION

Outflow onset may occur with little or no warning.

- Outflow (gusty and erratic wind) onset may occur with little or no warning.
- A period of relative calm may be observed prior to outflow onset.
- Visual indicators such as virga or a rain shaft will likely be obscured by smoke.
- Lightning is possible along with rain.



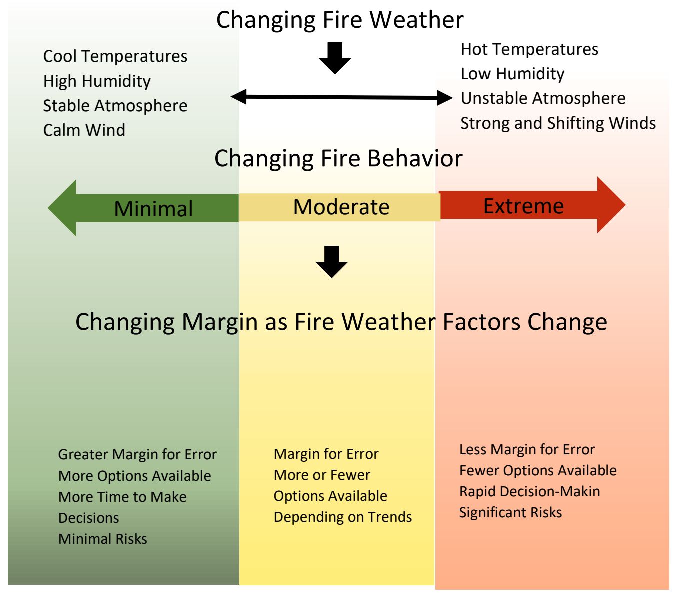
Fire behavior concerns are identical to thunderstorms.

★ QUESTIONS?

INCREASE OR DECREASE?

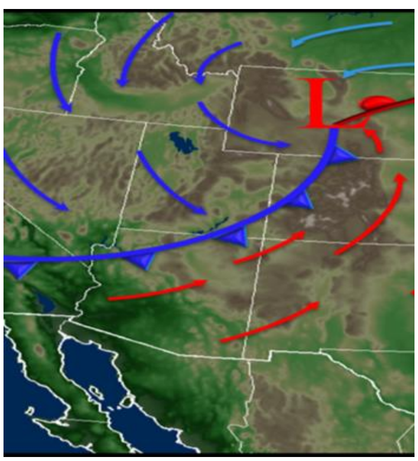
1 Changes in fire weather that include hot, dry, and windy conditions __________ the margin for error and increase risk.

2 Changes in fire weather that include cool, moist conditions __________ the margin of error and minimize risk.



WEATHER PHENOMENA

3 The _________ is the leading edge of a relatively cold air mass that may result in extreme fire behavior due to warm temperatures, low humidity, shifting and strong winds, and unstable atmospheric conditions.



4 A _______wind is a strong, warm, and dry wind that originates from areas of high pressure in mountainous regions.

4 Winds associated with a ______________ are typically gusty and erratic.

ANSWERS

1. ***Decrease***
2. ***Increase***
3. ***Cold Front***
4. ***Foehn***
5. ***Thunderstorm***

END OF UNIT 6

Please review the objectives below and answer the questions on your Task Sheet that relate to Unit6.

Objectives

- Describe critical fire weather conditions.
- Describe critical fire weather events such as cold fronts, thunderstorms, foehn winds, and other local phenomenon that can impact fire behavior.

UNIT 7 Alignment

Objectives

- Describe how the primary wildland fire environment components – fuels, weather, and topography are made more complex by interaction with each other.
- Describe how alignment of these components greatly increases the potential for extreme fire behavior.

FIRE ENVIRONMENT INTERACTIONS

The components of fuel, weather, and topography do not exist separate from each other, but instead interact in complex ways.

- **Topography-Weather:** Terrain features channel winds, or cause thermal belts that keep humidity's low through the night.
- **Topography-Fuels:** Fuels on south aspects tend to have less moisture because of solar heating. Timber on North aspects tends to be more dense and more prone to crowning. Steep drainages gather logs and other fuels that roll downhill.
- **Weather-Fuels:** Dry weather can turn plants that are normally a barrier into available fuel. Frost-killed leaves turn from live fuel to dead fuel and can dry quickly. Trees block the wind, reducing the intensity of fires in surface fuels below them.

WHAT IS ALIGNMENT?

Alignment is when the components of fuel, weather, and topography interact, and align to create optimal conditions for extreme fire behavior.

- Common factors contributing to alignment are:
  - Availability of dry, continuous fuels.
  - High temperatures combined with a wind component.
  - Topographic features in line with the predominant wind component.

Reference Alignments and Patterns for Dangerous Fire Behavior in the Incident Response Pocket Guide (IRPG)
https://www.nwcg.gov/publications/461

WATCH VIDEO: Alignment and Fire Behavior (6:08)
Introduction to the concept of alignment, and how it has caught firefighters unaware on the Salmon-Challis National Forest in Idaho. The video brings together the elements of the fire environment and how the alignment of these elements can, and has, resulted in extreme fire behavior. Alignment has caught experienced firefighters unaware, causing tragedies, and near-misses.
While watching the video: Think about the *concepts and terminology that relate to the alignment of fuels, weather, and topography.*

WATCH VIDEO: Predicting Fire Behavior (7:38)
How alignment of fuels, weather, and topography can produce fire behavior that is more intense than expected. The recognition of alignment by firefighters to aid in safer daily tasks on the fireline.

SUMMARY

- Recognizing the potential for alignment helps firefighters be safer and more effective at their job.
- Awareness of alignment indicators helps firefighters avoid being caught by unexpected fire behavior.
- Recognizing where and when those factors will fall out of alignment helps firefighters find opportunities to be successful.

END OF UNIT 7

Please review the objectives below and answer the questions on your Task Sheet that relate to Unit7.

Objectives

- Describe how the primary wildland fire environment components – fuels, weather, and topography are made more complex by interaction with each other.
- Describe how alignment of these components greatly increases the potential for extreme fire behavior.